AN EVALUATION OF A COMPUTERIZED C3
DECISION AID

Lawrence C. Shackleton

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN EVALUATION OF A COMPUTERIZED
C3 DECISION AID

by

Lawrence C. Shackleton Jr.

March 1980

Thesis Advisor: Ronald J. Roland

Approved for public release; distribution unlimited

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EVALUATION OF A COMPUTERIZED C3 DECISION AID		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lawrence C. Shackleton Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, Cailfornia 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1980
		13. NUMBER OF PAGES 110
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Decision aid; Decision support system; Computerized decision aid; Command, Control, and Communications (C3); Operations and Intelligence (OPINT)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A C3 system includes the data gathering (or intelligence) process, the decision making process, and the operating forces required to achieve a particular mission. Unfortunately, the majority of the resources spent in the improvement of these systems are expended in either providing better data gathering,

failsafe communications, or better weapon systems. Little thought is given to how the decision maker processes the data in order to make effective decisions. Several computerized decision aids have been suggested to fill this gap. One of these aids, Operations and Intelligence (OPINT) is evaluated to assess its utility as a computerized decision aid in C3 applications. OPINT is an on-line, interactive, real-time decision aid which assists decision makers by prescribing a straightforward normative procedure for organizing and analyzing difficult decision problems. The results of the experiment show that OPINT aids in the decision making process, but has some severe limitations as it currently exists.

Approved for public release; distribution unlimited

An Evaluation of a Computerized C3 Decision Aid

by

Lawrence C. Shackleton Jr.
Major, United States Army
B.A., Washington and Jefferson College

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY

ABSTRACT

A C3 system includes the data gathering (or intelligence) process, the decision making process, and the operating forces required to achieve a particular mission. Unfortunately, the majority of the resources spent in the improvement of these systems are expended in either providing better data gathering, failsafe communications, or better weapon systems. Little thought is given to how the decision maker processes the data in order to make effective decisions. Several computerized decision aids have been suggested to fill this gap. One of these aids, Operations and Intelligence (OPINT) is evaluated to assess its utility as a computerized decision aid in C3 applications. OPINT is an on-line, interactive, real-time decision aid which assists decision makers by prescribing a straightforward normative procedure for organizing and analyzing difficult decision problems. The results of the experiment show that OPINT aids in the decision making process, but has some severe limitations as it currently exists.

TABLE OF CONTENTS

LIST OF FIGURES

I. DESCRIPTION OF DECISION ANALYSIS

During times of crisis or war, there is probably no field of endeavor like military and strategic command and control where decisions are made quickly, but under conditions of risk and extreme uncertainty. This is especially true since accurate information on all aspects of a problem are almost always concealed from decision makers. Every military force tries to conceal itself and makes every attempt to deceive the opposing decision maker as to its intentions. Facts surrounding the tactical situation are elusive; especially those concerning the enemy. These types of decisions, then, are difficult and frequently would seem to defy a systematic decision making process (Department of the Army, 1980, p. 3-2). At the same time, there is no arena in which bad decisions have more tragic results. The cost of making errors can grow exponentially mainly due to the complex relationships and resulting chain reactions, or the errors could cancel themselves out and the costs not be immediately known (Turban and Meredith, 1977, p. 4).

Consequently, while decision makers must recognize that orderly, rational decision making procedures are difficult, they must at the same time constantly strive to base decisions on the most rational thought process possible. To reduce error probability, and for the sake of survival, decision makers must become more sophisticated (Turban and

Meredith, 1977, p. 5). They must learn to utilize new tools and techniques that are being developed. No one could imagine a successful surgeon utilizing equipment and procedures from the turn of the century. Yet, in decision making, you can still find decision makers using the tools and techniques of that time.

Military and strategic decisions are not only made under conditions of uncertainty (where not all facts are available) and stress, they are also rarely considered final. The ever changing situation brings with it the requirement to continuously revise appraisals, estimates, and perhaps decisions. This occurs since decision making is based on the future but is dependent on the past. For years, managers have considered decision making to be a pure art or talent which is acquired over a long period of time through experience or trial and error. It has been considered an art because a wide variety of individual styles can be used in approaching and successfully solving the same type of problems. One would normally base these styles on creativity, judgment, intuition, and experience rather than some sort of systematic method (Turban and Meredith, 1977, p. 5).

Decision making as a discipline had its origins in operational analysis techniques beginning in World War II (Williams, 1978, p. 12). These techniques were typically applied to special types of clear-cut, repetitive problems, such as those of systematic search and resource allocation.

Since the 1960's, however, a more general technology has emerged for imposing logical structure on the reasoning that underlies any specific decision. This technology is decision analysis (Barclay et al., 1977, p. iv). Since 1970, there has been a major effort by defense agencies to adopt this technology to their day-to-day decision making. Many have found it a way to make better, more defensible decisions.

Decision analysis is a quantitative method which permits the systematic evaluation of the costs or benefits accruing from courses of action that might be taken in a decision problem (Barclay et al., 1977, p. vi). The method includes the identification of the alternative choices involved, the assignment of values (costs/benefits) for possible outcomes, and the expression of the probability of those outcomes occurring. Once this is done, the probable gain or loss associated with each alternative can be determined by systematically combining the probabilities and values.

In addition to the primary role of decision analysis as a method for the logical solution of complex decision problems, it also has several additional advantages as well. The formal structure of decision analysis insures all the elements, their relationships, and their associated weights have been considered in the decision problem. The model of the decision problem can serve an important role in facilitating communications between those involved in the

decision process. Also it is very easy to identify the areas of disagreement, their relative importance, and if they actually have any material impact on the indicated decision. Finally, when changes occur in the problem, it is relatively easy to reenter the existing problem structure to change values or to add or remove problem dimensions as required (Barclay et al., 1977, p. vii).

It should be emphasized that in no sense does decision analysis replace decision makers or the role of human judgment in decision making. Intuitive, implicit, or judgmental decision making is, after all, the mainstay of the experienced decision maker and for good reason. Intuitive un-aided methods have typically served the decision maker well, and he/she can reflect on some personal history of productive reliance on their developing intuition (Brinkers, 1972, p. 191). There is considerable evidence to show that unaided decision making is reasonable, effective, and reliable (Peterson and Beach, 1967, pp. 29-46). However, what decision analysis does, is provide an orderly and more easily understood structure that helps to aggregate the wisdom of experts on the many topics that may be needed to make a decision, and then support the skilled decision maker by providing him with sound techniques to supplement and ensure the internal consistency of his judgment.

Complex decision problems are often difficult to resolve. This occurs for a number of reasons. Options are

not always clearly defined. Any results which may be derived from the selection of a particular option may be highly uncertain. Also, it is often difficult to determine relative preferences for the possible decision outcomes. When problems such as these do occur, the decision maker normally takes steps to structure the problem and reduce it to a more explicit form. This is exactly what decision analysis does.

Decision analysis builds upon four basic elements which are inherent in any decision problem (Barclay et al., 1977, p. 1). The use of these four elements allows for a smooth procedure in the resolution of complex decisions. The four elements are:

1. A set of initial courses of action. You must have more than one alternative or there is no decision to be made. All possible alternatives should be considered without regard to plausibility at this point.

2. The possible consequences of each initial act. These must be considered. What are the important things that can happen that will make one act more valuable or worth more than another act? Relevant sequences of subsequent events and follow-up acts must be identified for each initial act.

3. How attractive or unattractive is each

consequence of each act? How desirable or undesirable is one outcome compared to others which might result from the same or another decision.

4. How likely is it that a particular act will result in each of the consequences. This probability or uncertainty can be measured as a probability from 0 to 1 or in the form of odds.

These four elements, as described, provide a way to organize, quantify, and trace the logical implications of the decision. The primary objective is to provide a model of at least part (all would be best) of the decision. The use of the word model in this case means to represent the decision in a quantifiable form.

It is a central precept of decision analysis that all relevant considerations in a decision can be represented fully in a decision diagram (Barclay et al., 1977, p. 2). This decision diagram will show everything a decision maker feels is relevant to the problem in question. A decision diagram consists essentially of a network of branches corresponding to possible sequences of acts and events, fanning out from an origin at the left to a time horizon at the right. Acts are available choices. Events are possible occurrences which are partly or completely outside the decision maker's control, though the chance of one of them happening may be influenced by acts which were carried out

earlier.

The decision diagram graphically distinguishes acts from events. Act forks are represented by squares and event forks are represented by circles as shown in Figure 1.

These act forks and event forks are then combined to form a decision tree. An example of a tree is shown in Figure 2. This decision situation involves a company which must decide whether to bid on two projects, A and B. The decision on project A must be made prior to the decision on B.

This decision diagram depicts all the possible acts and events and shows how these relate to each other in the decision situation. While the representation would help a decision maker to see at a glance his alternatives and identify those things that might affect any choice to be made, it does not yet answer the central question: which choice should be made? That question can not be answered without considering the value of the possible outcomes and the likelihood of occurrence of the events. In order to show how this is incorporated into the decision model, let's return to the bidding example. Let's say it has been calculated it will cost $10,00 to prepare a bid for either project. If the bid on A is won, a gain of $50,000 will be realized. Project B will also return a gain of $50,000 if the bid is won but due to overhead, will only return a gain of $20,000 if bid A is also won. The decision tree now looks like Figure 3. The numbers shown at the right side of

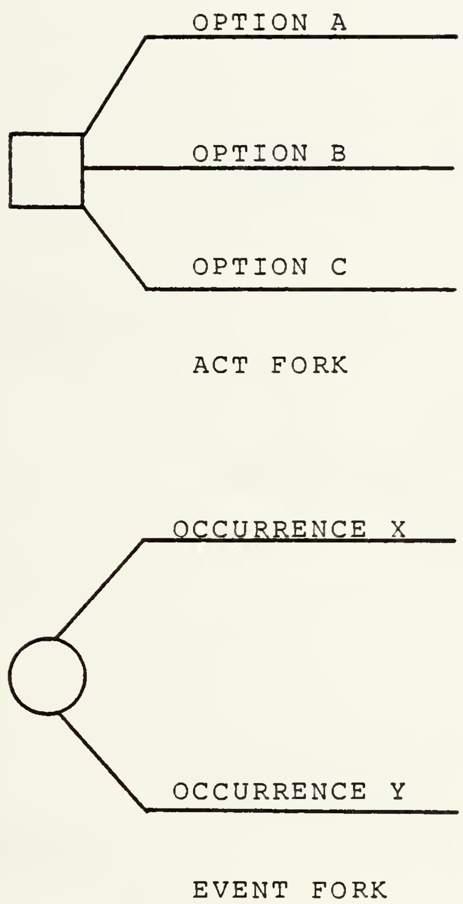


FIGURE 1: ACT AND EVENT FORKS

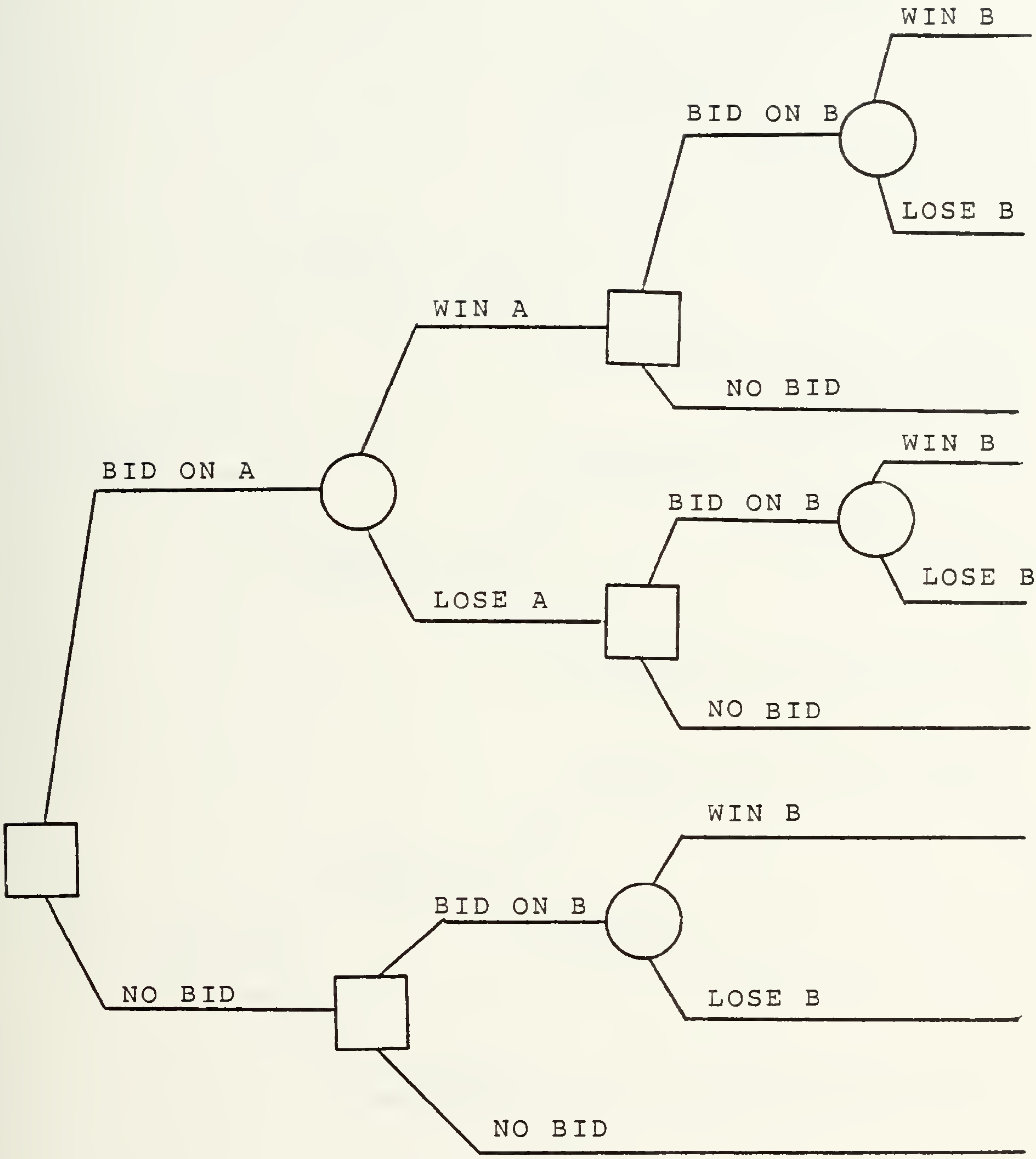


FIGURE 2: DECISION TREE STRUCTURE

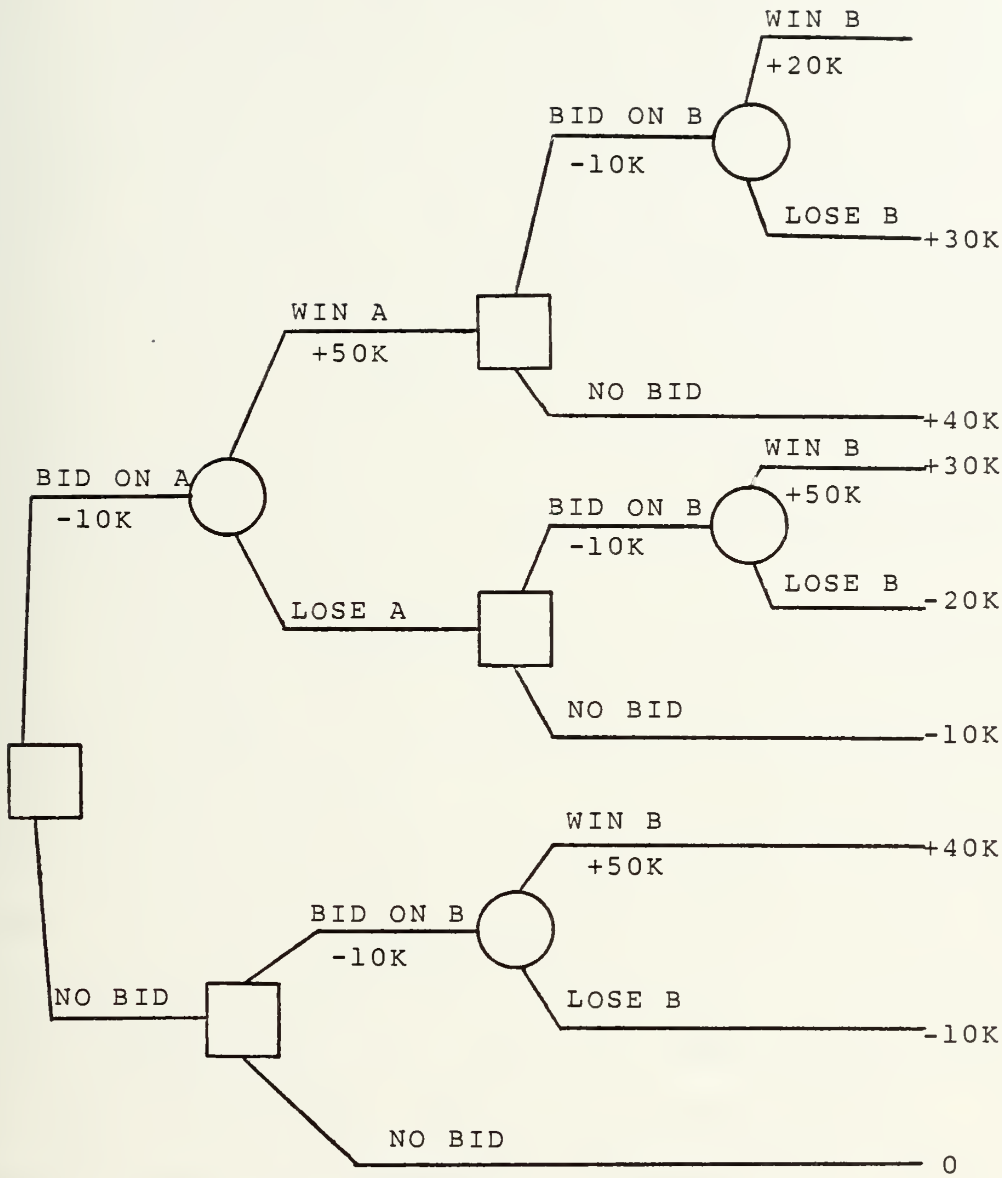


FIGURE 3: DECISION TREE WITH VALUES ADDED

the diagram are the path values. These values are the sum of the costs and gains along each path.

Now to complete the diagram, we need to portray the degree of uncertainty about the events we cannot control, specifically whether a bid is won or lost. Based upon prior experience, it is judged that the bid on project A is equally likely to be won or lost (probability .5 win, .5 lose). If A is won, the probability of winning the bid on B is reduced to .4. However, if A is lost, the chances of winning B increase to .7, and if A is not bid on, the chances for B are .6 to win. Adding these values leaves our diagram looking like Figure 4.

This diagram should now be a virtually complete translation or model of the perception of the decision maker of the decision problem. All that is left now is to determine which is the best solution. The method to do this involves the calculation of weighted values, often called expected values, for each decision option. This technique is the simplest and statistically most straightforward method that can be used. Care must be taken however, since frequently there are decision circumstances wherein an expected value solution to a decision problem may not be an optimal one. In these cases, alternative means of treating value are required and will be discussed later.

Determining a value for each act in a decision is done by a procedure called folding back the decision diagram. Values are substituted for each act and event fork beginning

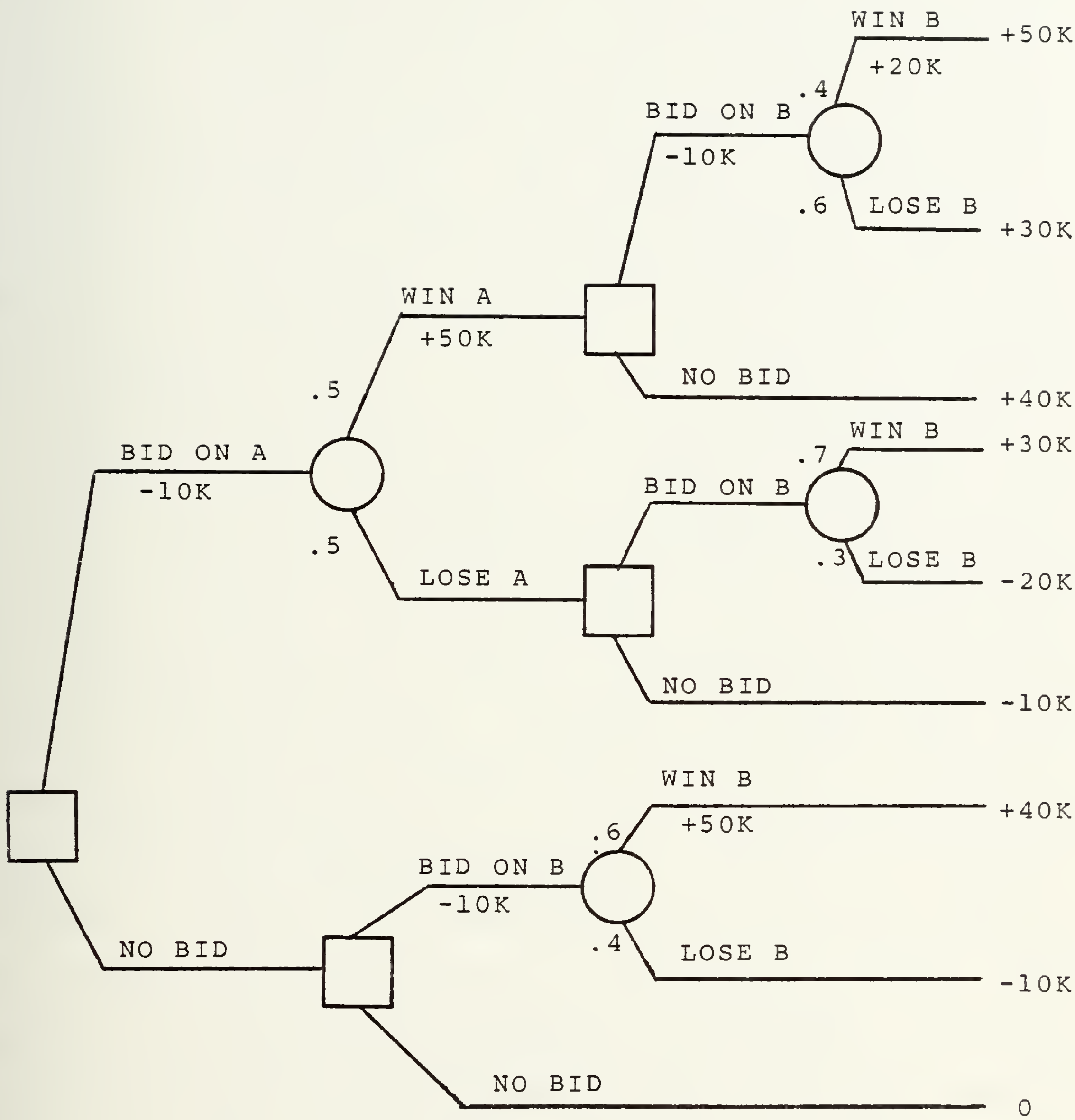
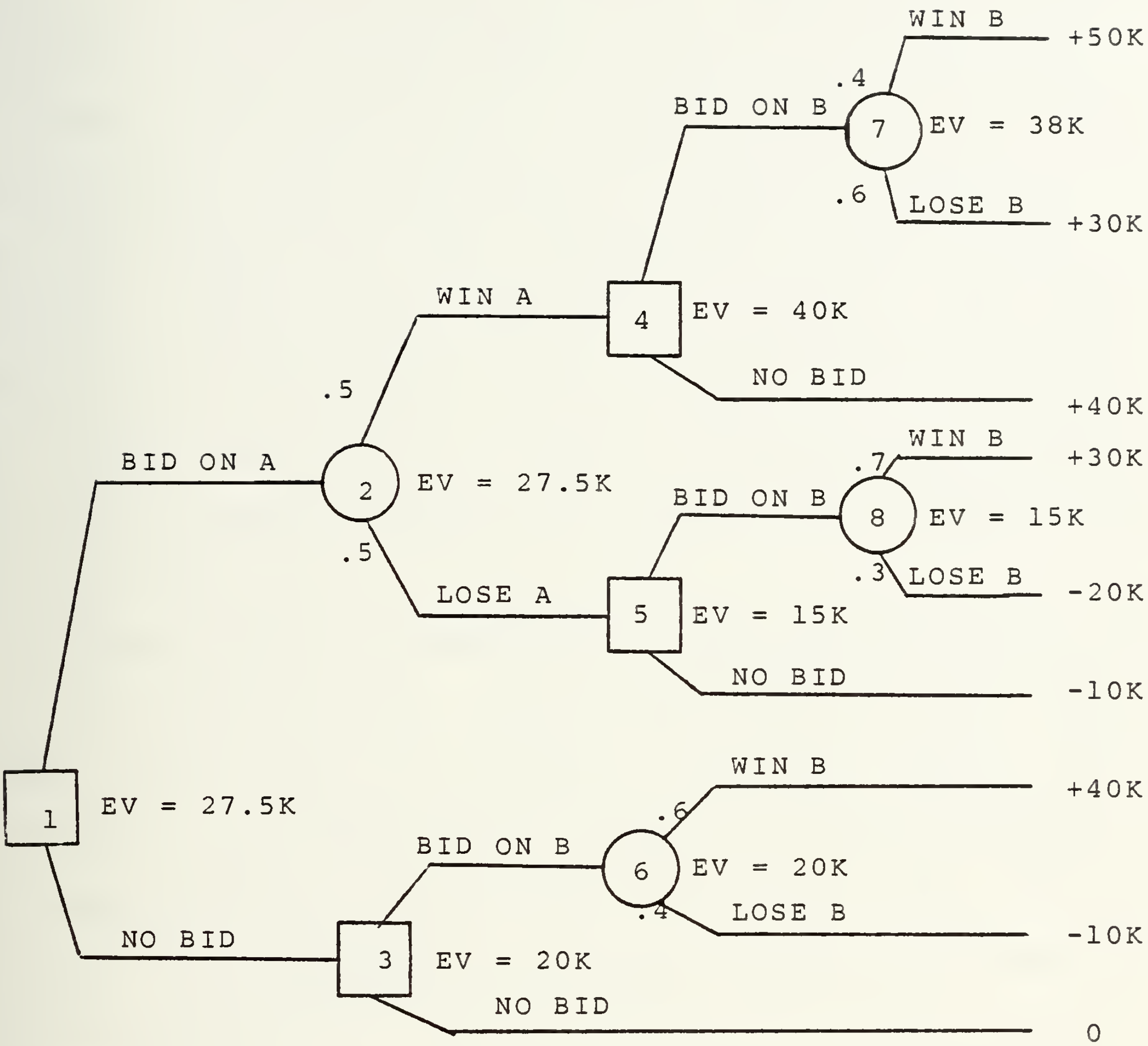


FIGURE 4: DECISION TREE WITH PROBABILITIES ADDED

at the right-hand side of the diagram. At each event fork, the expected value of that event is calculated by multiplying the value of each possible outcome by the probability of the occurrence of that outcome. At each act fork, the act with the highest value is the one which should give the best decision. The process of substitution is continued until the initial act fork is reached. Figure 5 depicts this procedure. Therefore the decision maker would bid on project A, then if he won the bid, not bid on Project B. If he lost the bid on A, he would bid on project B.

Thus far in the discussion of decision analysis, the values of the gains or losses were assigned in terms of only one measure, money. The outcomes were then compared, using the expected value, very easily since it is easy for us to relate to money as a value. However, in most real life situations, especially those of the military, gains and losses are not measured in money, rather in terrain, equipment, capabilities, and even lives (Williams, 1978, p. 22). These value dimensions are qualitative rather than quantitative and are very difficult to measure. To further cloud the issue, each individual has his own personal subjective values for each of these.

In addition, very seldom are these value dimensions or attributes given equal weight in a decision. For example, consider the selection of a radio set from several competing models. Cost may be an important consideration, but so are weight, range, portability, and reliability. Just how



EV(7) = (.4)(50K)+(.6)(30K) = 38K
EV(8) = (.7)(30K)+(.3)(-20K) = 15K
EV(6) = (.6)(40K)+(.4)(-10K) = 20K
EV(4) = LARGER OF 38K OR 40K = 40K
EV(5) = LARGER OF 15K OR -20K = 15K
EV(3) = LARGER OF 20K OR 0 = 20K
EV(2) = (.5)(40K)+(.5)(15K) = 27.5K
EV(1) = LARGER OF 20K OR 27.5K = 27.5K

FIGURE 5: DECISION TREE WITH EXPECTED VALUES

important each is requires determination. What is important in the decision is which of these attributes is more important than the others and how is this difference scaled. Then how do the remaining attributes fit on this scale. For instance, are cost and reliability equally important? If not, what exactly is the difference and how does the decision maker make trade-offs between the two. Determinations of this sort must be made for all attributes and somehow our model must be able to compare across these many attributes and aggregate the results to indicate the best solution.

Problems of this nature have spurred the development of multi-attribute utility models (Williams, 1978, p. 24). These models help to provide a relative ranking for attributes and also provide a common guide for aggregating the measures into a single index of worth. This process involves the assignment of a measure of utility or merit to the attributes.

Utility can be described as a subjective measure of "liking" (Barclay et al., 1977, p. 27). It is a personal value reflecting how you subjectively value something. The application of utility as a measure for the value of an attribute or alternative was first proposed by Von Neuman and Morgenstern. They suggested that each individual has a measurable preference among various choices available. The preference they called utility and is measured in arbitrary units called utiles (Von Neuman and Morgenstern, 1944, p.

27). Utility is based on the concept that in decision making, a person will choose that alternative which maximizes his or her expected utility .

Multi-attribute utility models have been used extensively in the systems acquisition role (Williams, 1978, p. 23). The procedures encourage discussion among the decision maker and his staff. No longer can cost be a little more important than reliability. It is now, perhaps, ten utiles more important. Once the values are assigned to the model, and a best decision decided upon, the model now allows you to vary the relative weights to see which ones have the most impact on the proposed solution. This is called a sensitivity analysis and helps decision makers when they are uncertain about the accuracy of their information.

Decision analysis applies Bayesian techniques to place a value on information that reduces uncertainty (Keen and Scott Morton, 1978, p. 44). Bayesian techniques provide formal methodologies for analyzing the implications of a decision maker's subjective judgment of probabilities, updating these assessments as additional information is obtained. This additional information can result in one of two events: either the uncertainty is completely removed or the additional information allows the decision maker to revise the initial (prior) assessment of the probabilities (Keen and Scott Morton, 1978, p. 46).

As stated earlier, the use of decision analysis does not replace the decision maker but adds a new dimension to

his decision making capabilities. It is also assumed the use of these manual techniques could slow the decision making progress considerably, especially if a fear of mathematics exists. Fortunately, what has been developed are decision aids which greatly ease the complexity involved.

A decision aid is a human-system interface designed for the specific purpose of supporting and enhancing a decision maker in his decision making role (Keen and Scott Morton, 1978, p. 58). It is a tool for use by the decision maker. Decision aids are normally stored on computers as the use of the computer reduces all needs for calculations by the decision maker and helps to speed the decision process.

The general availability of low cost, high capacity, fast information processing technology has enabled man to extend and increase his intellectual capacity. The effect of this has been that man can now deal more effectively with complex matters on his own complex terms as against the more simplistic terms of pre-information technology man (Brinkers, 1972, p. 5). The focus is not on the computer itself, but on the technology for dealing with the information that is available and the scientific methods which are in development and use.

The use of decision aids normally places increased demands upon human creativity and judgment rather than relieving the decision maker of the need to exercise them as might be expected. This is because the availability and use

of decision aids which serve as an extension of the decision maker's intellect provide new and interesting opportunities for using his intellect. Decision aids help the decision maker by prescribing a straightforward normative procedure for organizing and analyzing difficult decision problems involving both uncertainty about the outcome of future events and perplexity about the complex value tradeoffs involved in the choice of a course of action (Brinkers, 1972, p. 7).

t decision aids which serve as an extension of the decision aker's intellect provide new and interesting opportunities or using his intellect. Decision aids assist the decision aker by prescribing a systematic and analytic procedure or organizing and evaluating difficult decision problems nvolving both uncertainty about the outcome of future vents and complexity about the complex value tradeoffs nvolved in the choice of a course of action (Peterson, 972, p. 1).

II. USE OF DECISION AIDS WITHIN THE C3 ARENA

Command, control and communications (C3) can be defined as a process which provides the commander (or decision maker) with a means of receiving information, making decisions based on this information, and then implementing and monitoring the decision in order to achieve his or her mission (Moose, 1980). A C3 system includes the data gathering (or intelligence) process, the decision making process, and the operating forces (or weapons) required to achieve the mission. A C3 system would look somewhat like the figure shown below.

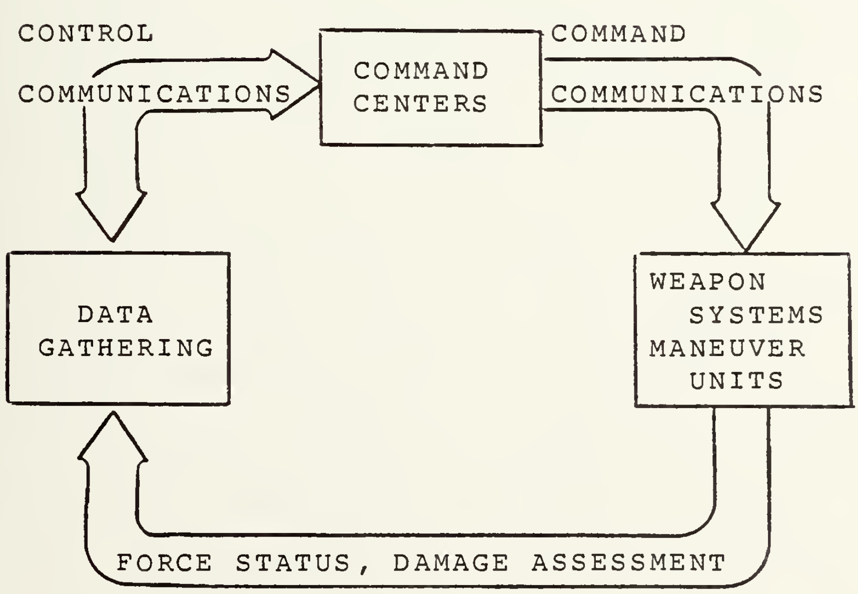


FIGURE 6: C3 SYSTEM

This figure shows that data is gathered, possibly through the use of early warning radars, photography, or reports from within, and sent to a command center. Once within the command center, the data is analyzed and a decision is made regarding the use of weapons or units. These decisions are then transmitted to the respective units for implementation. Requirements for data or information could originate at the command center or it could be spontaneously generated as in the case of a missile attack.

Unfortunately, the majority (if not all) of the resources spent in the improvement of these systems are expended in either providing better data gathering (such as better radars), failsafe communications, or bigger and better weapons systems. These are all important aspects and should be improved, but this is also indicative of the lack of appreciation for what must be done with the data when it is delivered to the command center. Little thought is given to how the decision maker processes the the data in order to make effective decisions and forecasts.

The amount of data available today to decision makers is mindboggling. Realistically, if methods for cognitive information processing are not improved at the same rate as our communications can provide it, much, if not all of our sophisticated communications technology will go under utilized. What is needed is more research aimed at improving our information management, decision making, and forecasting utilizing the applications available through the

computer (Andriole, 1980, p. 1).

Decision making lies at the heart of the C3 process (Andriole, 1980, p. 12). The entire C3 system focuses on providing a means to transmit all required data to the decision maker and then a means to transmit the decision to the required parties. Therefore, C3 systems which do not contain some sort of decision making support should be challenged because they are incomplete.

Most decision makers will begin with a need for some background information on the problem at hand. Has there been a problem like this before? How have the people involved reacted in similar situations? Are there any people available who have experience in this area? These are all examples of the types of questions which will need to be answered.

Next, the decision maker will want all of the latest facts surrounding the problem. Who is available to move into the area? How long will it take? Who is there already? What forces does the opposing side have available? What is happening now? These and many more are the questions surrounding the current situation.

Now, the decision maker will want to know what the options are and what the adversaries options are. In addition, will be the need to know of any activities, either in process or pending, which may have an impact on the decision. Next is the assessment of the probabilities of the possible outcomes of these activities. The criteria

which will be used in analyzing the alternatives must be listed and relative importance weights for these determined. Finally the decision maker evaluates the alternatives and selects a course of action to be followed.

How does the decision maker do all this, especially when the impacts of a wrong decision can be so costly? It certainly can not be done alone. The decision maker must rely on the aid of key staff members who have certain expertises in specific areas. But even with competent staffs, the task is often too great. Computerized decision aids may be the only answer.

There are several reasons why computerized decision aids would be useful in the C3 decision making process (Allen et al., 1976, pp. 2-5). These reasons are:

1. It is an effective tool for improving the dialogue among staff officers who are working together on a particular problem. It would be helpful in eliminating misunderstandings.

2. The process of using a decision aid gives staff officers the opportunity to include what they considers important in the analysis. Then they can see how these factors actually impact on the solution.

3. It is very easy to evaluate several courses of action. Variables which are uncertain can be changed to allow for the best and worst cases in

the analysis.

4. Critical areas can now be focused on. All too often, too much time is wasted in discussing or arguing what may seem to be important points, but turn out to be rather insignificant in the final solution.

5. Time may now be in your favor rather than your opponent. Most people do not react well when under time constraints. People tend to over react to unimportant events and make quick and hasty judgments. Decision aids enable and force the decision maker to follow a systematic routine. Then the aid performs the necessary calculations in a real time manner. This gives additional time to either wait for additional information or actively seek for it if the analysis shows a need.

There are numerous examples of C3 problems where computerized decision aids would be useful and the following are some examples:

1. Decision aids can and are being used to monitor early warning systems for any indications of impending crisis. It is important to not allow events to control us, but rather to possibly have us shape the events (Andriole, 1980, p.

30).

2. A recent example concerned the analysis of different evacuation postures that a commander was considering in the face of uncertainty about a developing crisis that could have made it necessary to evacuate U.S. nationals from a third country (Williams, 1978, p. 27).

3. The normal contingency planning process that constantly takes place is another example (Williams, 1978, p. 28). The decision aid allows you to easily play the "what if" game.

4. Training is another example. By allowing staff officers the chance to use the aids based on past crises, they become familiar with current plans and procedures and, if realistically used, become used to operating in a crisis environment (Allen et al., 1976, p. 5).

5. Decision aids may be used for establishing policy. Options can be evaluated and tested prior to deciding on firm policy.

6. The design of new C3 systems would be another example. Whenever new systems are designed, there is always a tradeoff of capabilities because of insufficient funding. These aids would help determine the safest cuts in

capabilities to be made.

III. EXISTING C3 DECISION AIDS

This chapter describes several C3 computer-based information, decision, and forecasting systems designed to link the human user with the information so critical to efficient information management.

There presently exists much too little emphasis upon the content and especially the form of the information and data that flow through C3 systems (Andriole, 1980, p. 3). The questions of how the information should appear to the user, how the information should be stored, retrieved, and manipulated, and how the ever increasing amounts of information can be comprehended by the user have not been adequately dealt with up to this point. The three computer-based information systems described below were developed with these questions in mind. Each is aimed at helping the C3 system users deal with the enormous amount of information for which they are responsible. The systems were developed with the human user in mind and thus exploit and supplement existing human information processing capabilities.

Spatial Data Base Management - The use of normal data base management systems, from the perspective of the occasional user, are difficult and inefficient (Andriole, 1980, p. 3). Recently, research has produced a prototype spatial data management system which enables users to

hierarchically store, retrieve, and manipulate data through the use of spatial controls (Andriole, 1980, p. 4). These spatial controls allow the user access to data without the need or use of the conventional keyboard. Instead, the spatial controls permit access to data using numerous navagational aids, such as color, location (in an electronic workspace projected on a large screen display), touch, and sound. Specifically, the user may store and retrieve the data according to where he or she finds it most easy to access.

The spatial data management system was developed in accordance with the way humans normally store and retrieve information. For example, in a normal office environment, people store information in familiar places according to frequency of use, importance, shape, size, and so forth. The prototype spatial data base management system uses these psychological predispositions by allowing the user to create his or her own psychological workspace and project it onto a large display. This display then is interactive and capable of storing all types of data to include numeric, photographic, and even audio. It is also easy to update. The user is then able to manipulate and retrieve data by moving through the workspace with joysticks or touch sensitive display panels. Figure 7 shows the hierarchical data organization principle. Figure 8 shows a user positioned in front of a spatial data base management system. Figure 9 shows the joystick and touch panel mounted

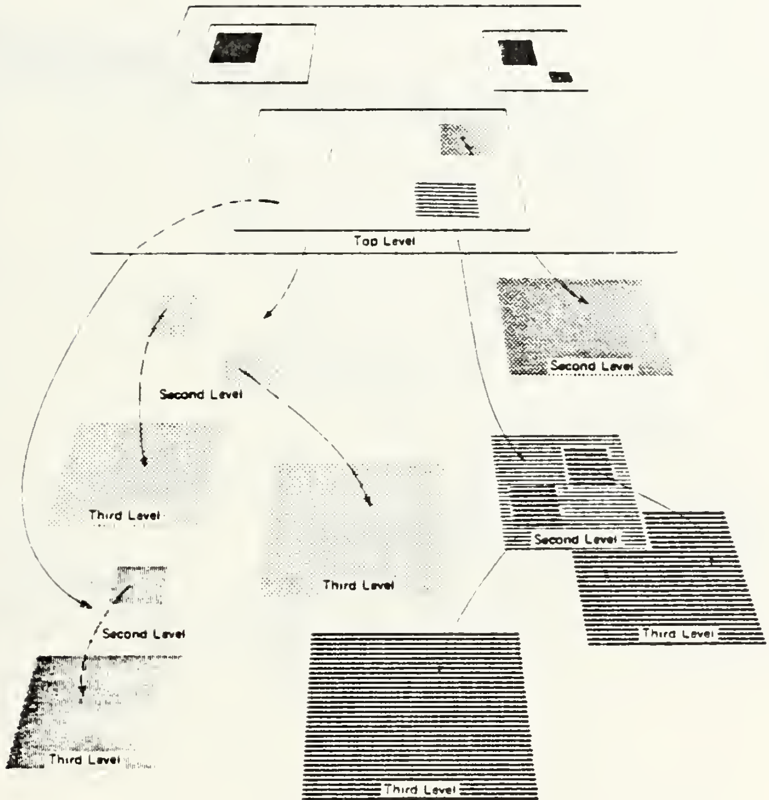


FIGURE 7: HIERARCHICAL DATA STRUCTURE
(Andriole, 1980, P. 5)

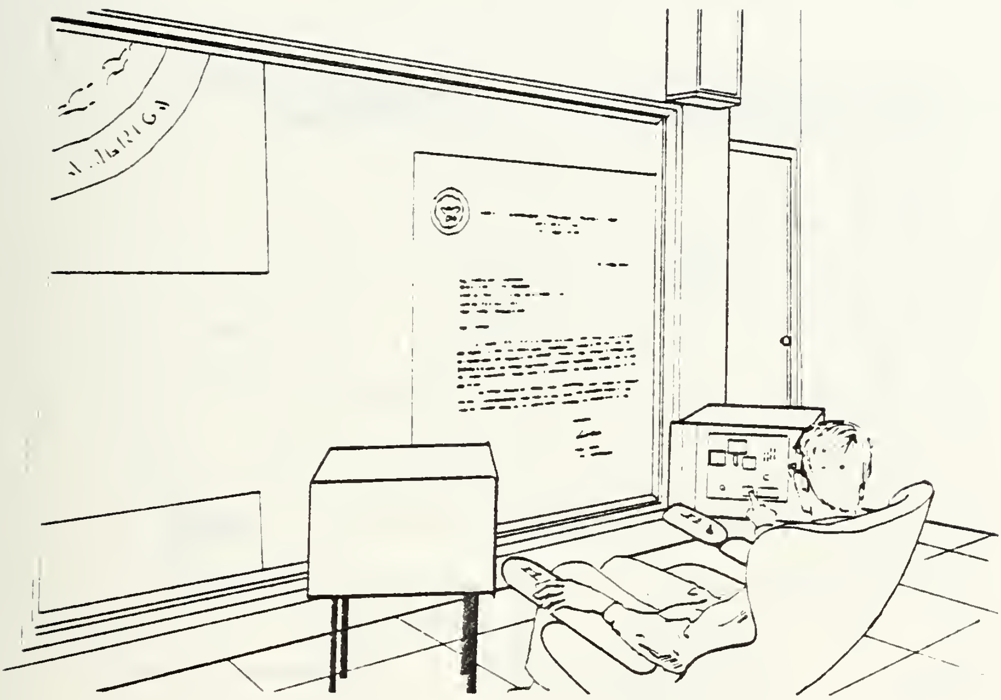


FIGURE 8: THE PROTOTYPE SPATIAL DATA MANAGEMENT SYSTEM (Andriole, 1980, P. 5)

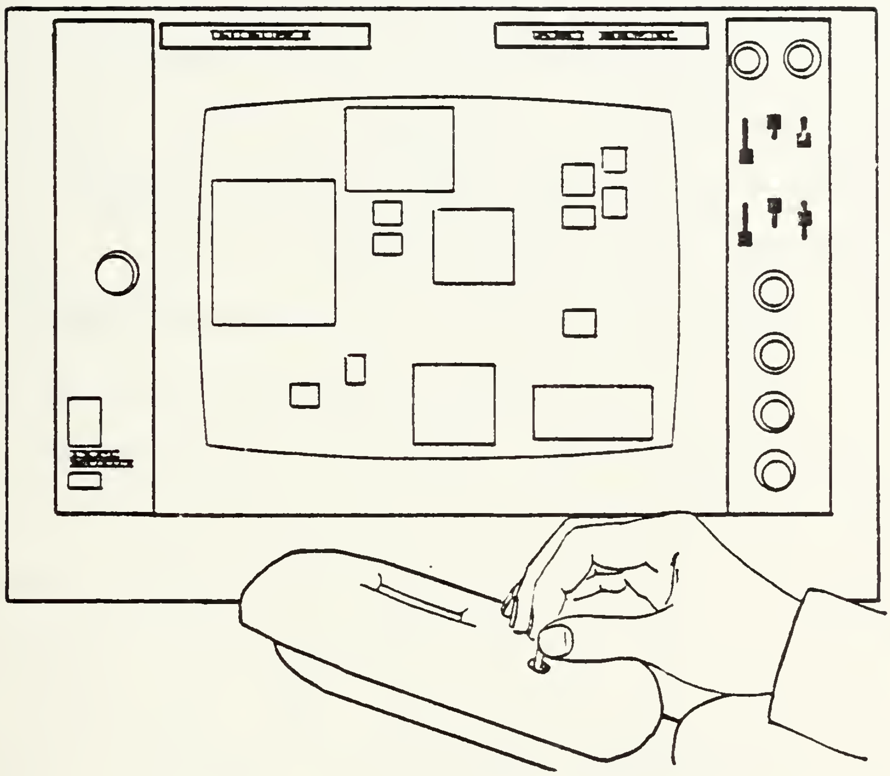


FIGURE 9: DATA ACCESS CONTROLS
(Andriole, 1980, P. 6)

in the arm of a user's chair. Data is accessed by touching a specific point in the workspace or the touch-sensitive pad and/or by moving the joystick forward or backward (to ascend or descend into the hierarchically organized data base).

Adaptive C3 Information Selection - In response to the ever increasing information requirements placed upon intelligence officers responsible for analyzing and routing information, the Adaptive Information Selector (AIS) was developed (Madni et al., 1979, p. I-3). During this development process, it was determined that "new C3 techniques are required to control information flow so as to best match system capability with human characteristics in the man-computer interaction".

The AIS process is as follows. The system user is calibrated during a training phase to determine how and why some messages (pieces of information) are selected for further analysis and some are rejected. This is performed for each individual user such that he or she has a personalized information management sorting, routing, and queuing system.

What happens, in effect, is the computer monitors the user and then internalizes how the user selects and rejects information. Once the training program is accomplished, the computer emulates the user and automatically selects, routes, and queues the information. Thus the AIS may be viewed as an information management assistant capable of relieving its superior from some of the burdens of

information overload.

The functions and elements of an AIS are presented graphically in Figure 10.

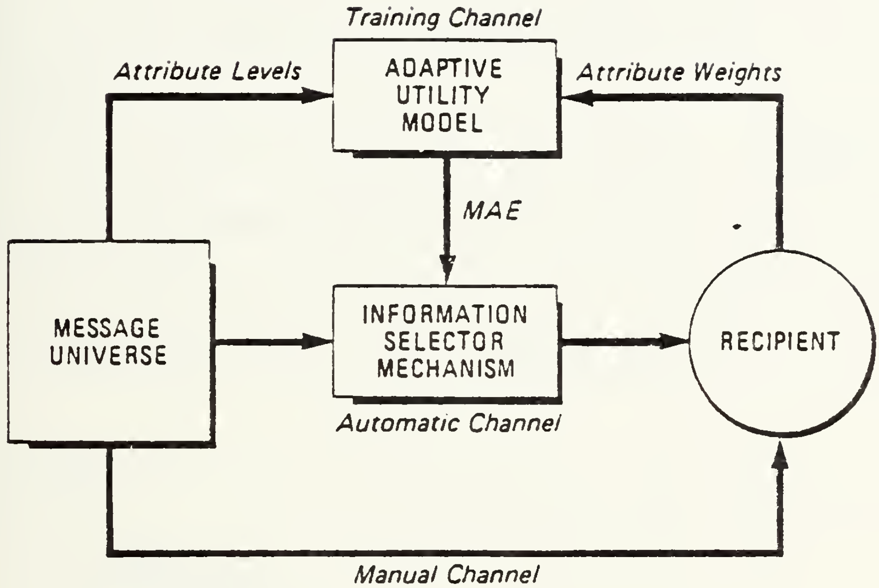


FIGURE 10: ADAPTIVE INFORMATION SELECTION SYSTEM CONCEPT (Andriole, 1980, P. 8)

The AIS has been developed for use where C3 information is already in an electronic form. The AIS is designed to support areas which are already complicated with too much incoming information for the human user to handle. The AIS is merely a computer program which provides help to the C3 system user.

Ultra-Rapid Reading - Even if systems such as spatial

data base management and AIS can quickly provide access to needed information, the user must still read and comprehend the information before further action can be contemplated. Subsequently, research has been performed to improve the speed with which users can read and comprehend (Andriole, 1980, pp. 9-11).

A technique known as rapid serial visual presentation (RSVP) has been developed and computerized for use in C3 systems. The text is presented one word at a time on a cathode ray tube (CRT) in rapid succession as Figure 11 suggests.

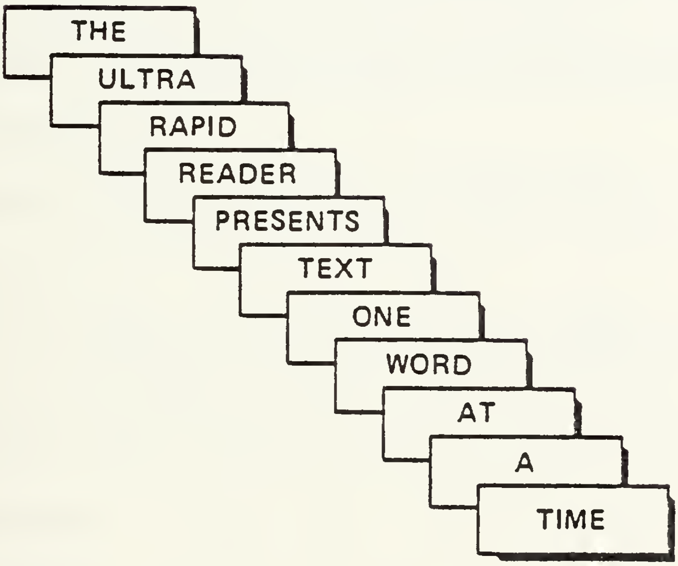


FIGURE 11: ULTRA-RAPID READING
(Andriole, 1980, P. 10)

Research has indicated that single RSVP sentences can be read and accurately recalled when shown at a rate as high as 12 words per second, which is twice as fast as people normally read (Potter et al., 1979, p. 1).

Reading speed and comprehension is a function of the time it takes for the eyes to transmit to the brain and the brain's ability to process. The ultra-rapid reader was developed to shorten the time between the eyes and the brain. It does this by reducing eye movement to a bare minimum. The eyes do not need to move back and forth or up and down, as is normally done, since the text appears on the CRT in the same location. In addition, substituting some pictures or symbols for words has increased comprehension. However, as with AIS, the text must be in electronic form to be read ultra-rapidly.

The preceding three research designs were directed toward improving the information flow to the decision maker. The next three examples are computerized decision aids which are designed to be used primarily during crisis situations. Each permits the user to select and retrieve history on past crisis situations. The best way to describe each is by providing a sample of the types of queries which are allowed. The first, as described in Figure 12, enables a user to retrieve and prescribe crisis actions (or responses) and objectives. The second aid, as shown in Figure 13, enables a user to focus on the management problems which occurred during past crises. The third aid enables a user

to examine 307 crises involving the U.S. between 1946 and 1976, as Figure 14 shows.

These aids were developed in direct response to requests from crisis managers for some type of on-line analytical assistance (Andriole, May-June 1979, p. 15). Crisis managers are now able to assemble, sort, and analyze crisis management data on a real time basis. Preliminary performance tests of these aids suggest they might increase the range of option generation and evaluation during crisis by 100% and reduce past search case time by 50%.

THIS SECTION IS DESIGNED TO ASSIST DEPARTMENT OF DEFENSE PERSONNEL IN EVALUATING PROPOSED COURSES OF ACTION AND SETS OF U.S. OBJECTIVES BASED ON DATA FROM 101 CRISES INVOLVING THE UNITED STATES BETWEEN 1956-1976.

THE USER IS GIVEN THREE LEVELS OF ANALYTIC ASSISTANCE:

1. THE CAPACITY TO SEARCH FOR HISTORICAL CASES WITH SETS OF USER-SPECIFIED U.S. ACTIONS OR OBJECTIVES.

2. THE CAPACITY TO IDENTIFY, ACROSS ALL CASES, THOSE ACTIONS THAT HAVE HISTORICALLY BEEN MOST STRONGLY ASSOCIATED WITH EACH OBJECTIVE SELECTED BY THE PROGRAM-USER;

3. THE CAPACITY TO IDENTIFY, ACROSS ALL CASES, THOSE ACTIONS THAT HAVE HISTORICALLY BEEN MOST COMMONLY ASSOCIATED WITH SETS OF U.S. OBJECTIVES SELECTED BY THE PROGRAM-USER.

WOULD YOU LIKE TO SEE A SUMMARY OF ANOTHER SYSTEM SECTION?
PRESS 'Y' OR 'N' AND 'RETURN'.

Y
ENTER 'I', 'II', OR 'III'.
II

FIGURE 12: CRISIS MANAGEMENT DECISION AID
(Andriole, 1979, P. 16)

THIS SECTION PERMITS A DETAILED EXAMINATION OF MANAGEMENT PROBLEMS ENCOUNTERED IN 41 SELECTED CASES (1956-1976).

MAJOR PROBLEM CATEGORIES ARE:

1. SYSTEM-RELATED DELAYS IN DECISION-MAKING
2. SYSTEM/PROCEDURAL CONSTRAINTS ON ACTIONS
3. LEGAL ISSUES INVOLVED
4. RESOURCES INADEQUATE FOR DECISION-MAKING/ACTION
5. INTELLIGENCE FAILURES AT DECISION-MAKING LEVEL
6. EMOTIONAL/IDEOLOGICAL ISSUES INVOLVED IN DECISIONS
7. INTERPERSONAL FACTORS IN DECISION-MAKING
8. PROLONGED CRISIS PROBLEMS
9. PROBLEMS IN SELECTING ACTION PERSONNEL
10. CONSTRAINTS ON OPERATIONS
11. PHYSIOLOGICAL PROBLEMS FOR OPERATING FORCES
12. INFORMATION FAILURES BY OPERATING FORCES
13. FAILURES IN TAKING APPROPRIATE/TIMELY ACTION
14. FORSTAT PROBLEMS
15. PROBLEMS IN THE OPERATING ENVIRONMENT
16. GENERAL PROBLEMS IN CRISIS PLANNING
17. GENERAL PROBLEMS IN CRISIS HANDLING
18. GENERAL PROBLEMS IN CRISIS TIMING

WOULD YOU LIKE TO SEE A SUMMARY OF ANOTHER SYSTEM SECTION?
PRESS 'Y' OR 'N' AND 'RETURN'.

Y
ENTER 'I', 'II', OR 'III'.
III

FIGURE 13: CRISIS MANAGEMENT PROBLEM ANALYZER
(Andriole, 1979, P. 17)

THIS SECTION PROVIDES ACCESS TO INFORMATION ON 307 CRISES (1946-1976).
THE DATA MAY BE SEARCHED FOR CASES MATCHING THE USER'S SPECIFICATIONS,
OR A FULL DESCRIPTION MAY BE PRINTED FOR ANY SELECTED CASE.

CATEGORIES OF INFORMATION CODED FOR EACH CRISIS ARE:

- YEAR AND BRIEF DESCRIPTION
- LOCATION OF CRISIS
- NATURE OR PRE-CRISIS ACTIVITY
- DURATION OF PRE-CRISIS PERIOD
- SCOPE OF CRISIS (DOMESTIC OR INTERNATIONAL)
- NATURE OF CRISIS (MILITARY, POLITICAL, BOTH)
- CRISIS DURATION
- TIMING OF CRISIS RESOLUTION
- CRISIS OUTCOME
- ANTICIPATION OF CRISIS
- DEGREE OF THREAT TO U.S. INTERESTS
- TIMING OF THREAT DEVELOPMENT
- TIME AVAILABLE FOR DECISION
- SIZES OF PARTICIPANTS/DEGREE OF U.S. INTERESTS
- U.S. RESPONSE/PARTICIPATION
- U.S. OBJECTIVES
- NUCLEAR/NON-NUCLEAR IMPLICATIONS

WOULD YOU LIKE TO SEE A SUMMARY OF ANOTHER SYSTEM SECTION?

PRESS 'Y' OR 'N' AND 'RETURN'.

N

FIGURE 14: CRISIS DESCRIPTOR
(Andriole, 1979, P. 17)

During crisis situations, decision makers strive to react swiftly, decide wisely, and communicate accurately. This requires close coordination with their staffs and the ability to overcome certain obstacles such as pressures from time constraints, ambiguity of goals, and the monopolization of time with information collection. Some of the problems of information collection have been solved or at least aided by the use of one or more of the previously discussed aids. What the decision maker now needs are effective decision strategies that impose rigor and provide a logical, structural framework to assist them in the process of choosing an optimal decision alternative in the face of voluminous and often inconclusive evidence.

Operations and Intelligence (OPINT) is a decision tool that provides just such a framework for deliberation, reasoning, and analysis (Amey et al., 1979, p. 3). OPINT is an on-line, interactive, real-time model which aids decision makers by prescribing a straightforward normative procedure for organizing and analyzing difficult decision problems. These problems may involve both uncertainty about the outcome of future events and perplexity about the complex value trade-offs involved in the choice of a course of action.

OPINT is a decision-analytic based, computer assisted decision aid. Its primary objective is to provide decision makers a procedural framework, or decision template, that insures their ultimate decision choice is a coherent one. A

coherent choice is one which is consistent with their own value structures and beliefs about the relative likelihoods of future events that will impact the decision outcome (Amey et al., 1979, p. 3).

The fundamental product of OPINT is a computer-stored conceptual representation, or decision model, of the decision problem at hand. Whereas decision analysis provides the theoretical background and procedural guidance, the OPINT decision model provides the specific methodological tool for processing information and evaluating the various decision alternatives open to the decision maker. An in-depth explanation of how OPINT aids in the decision process is discussed in Chapter Four.

Evaluation (EVAL), another on-line, interactive, real-time model, incorporates another decision strategy which provides the decision maker with a normative procedure for analyzing difficult decision problems. It is especially designed to evaluate and compare possible options using a multi-attribute utility analysis technique. EVAL is best applied to procurement decisions wherein systems are compared, but is appropriate for a diverse set of decision analytic problems (Decisions and Designs, Inc., 1977, pp. 1-5).

The use of EVAL is broken into two phases. First, the decision maker creates the structures of a hierarchical multi-attribute evaluation model using the EVAL Structure program. Then, this model is evaluated and processed using

the EVAL program.

In order to utilize the EVAL Structure program, the problem must be decomposed into a hierarchical structure which reflects the logical interrelationship of all the factors involved. This structure is then entered and the model is created. Now under the direction of the EVAL program, the criterion used for evaluating the alternatives are entered. Once entered, their respective weights of importance are entered. Next, the relative score which each alternative achieved for each criteria is entered. For example, consider three radio sets which are being evaluated for selection before procurement (A1, A2, and A3). The criterion of evaluation are cost, range, portability, and reliability. Each of these criteria are weighted 30%, 20%, 10%, and 40% respectively. Next, the three radio sets are evaluated according to each criteria using an arbitrary utility scale. Cost would show scores of 50 for set A1, 40 for set A2, and 80 for set A3. This means A3 is considered to have the best cost. This process is repeated for each criteria. It is also normal for the criteria to have sub-criteria which would also require the same procedure.

Next, EVAL gives the evaluation scores for each of the alternative systems resulting from the aggregations prescribed in the model structure. Now the decision maker can examine the effect of the criterion weights through a sensitivity analysis. This will quickly show him which criteria are the critical ones and take action to insure the

data surrounding that criteria is as accurate as possible. EVAL does not do anything the decision maker himself could not have done himself. What it does do, however, is allow him not to be pressed by time or to worry about computational procedures. He can play the "what if" game and feel confident about the decision he must make.

Another decision aid has been developed to assist groups in deciding how to deal with important issues or problems. Its purpose is the improvement of decision making by continuous participant interaction with the computer during the decision making process (Leal et al., 1978, p. 1-1). Members of the group are allowed to input their respective estimates of the occurrence of specific events and their values (weights) of the importance of specific decision outcomes. The decision aid then compares the input and informs the group members of any disagreements between them. But most importantly, it focuses the discussion only on the disagreements which are important to the stated goal. The differences which are not important are shown to be just that. Finally, it suggests to the group precisely how their disagreements might be resolved. This enables groups to move much more quickly toward decisions. As a by-product, profiles are developed of the participants which show who has expertise in special areas as well as who is a risk-avoider or risk-taker (Leal et al., 1978, pp. 1-3 to 1-10). The function of the aid is shown in Figure 15.

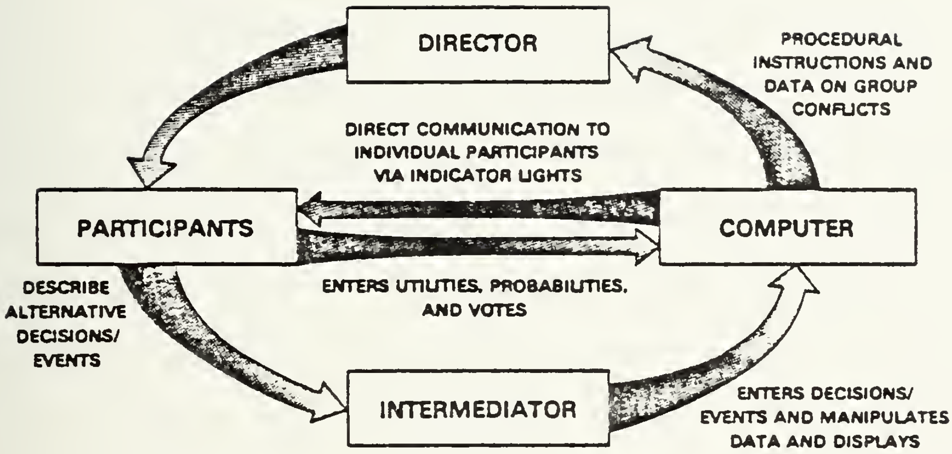


FIGURE 15: THE GROUP DECISION AID PROCESS
(Andriole, 1979, P. 17)

The decision group is composed of the participants (decision makers), an intermediator, and a director. The intermediator's primary function is to facilitate communication between the group and the computer. This is done by translating spoken requests into computer inputs. These inputs could be lists of events, alternative actions, requests for displays, or modifications to any previous inputs. The director helps with the output by presenting and explaining it to the participants. The director also focuses the group's activities and insures the inputs are appropriate. As a result, virtually no participant training is needed to operate the system, and a

group can begin work on its decision problem almost immediately after it is convened.

Another computerized aid, the Early Warning and Monitoring System (EWAMS), has been developed to aid the Indications and Warning (I&W) community. EWAMS provides them with an interactive computer based system of political, military, and domestic indicators for daily monitoring of international and intra national affairs (Daly, 1978, p. 4). The system has the capability to store quantitative international political data from 1966 for most countries of the world and can therefore be used to do retrospective analysis as well as current, daily I&W. The data is aggregated by month, quarter, and year. EWAMS has the capability to track single countries, combinations of country-pairs, regions or the entire world with these quantitative indicators, or specific regions may be specified (Daly, 1978, p. 6). At present, there is some doubt as to whether EWAMS will ever be fielded because its operation is extremely slow. But the concept is a good one and further research may prove beneficial.

The EWAMS is comprised of the following components (Andriole, 1980, pp. 28-34):

1. General Scans - A general scan is an aggregation of countries by some criteria, e.g., a scan defined by geographic region would aggregate countries by groups such as Latin America or Middle Eastern. A general scan allows an

analyst to look at several countries taken together rather than looking separately at many country-pairs. If the indications for the group as a whole suggest unusually high activity, tension, or uncertainty, the analyst can drop to the country-by-country level or even track the recent activity of a single country to determine the source of the disturbance or the regional level. General scans thus make the system much more efficient and less time consuming for the analyst.

2. Quantitative, Political, Military, Economic, and Domestic Indicators - Quantitative indicators for crisis warning include foreign, domestic, and international political, military, and economic factors. The indicators are both dynamic (events-based) and static (attribute based).

3. Multi Method Forecasting Capability - The unified multi-method forecasting capability requires the system to generate different kinds of forecasts or warnings via different methods for different events and conditions.. Such options have been designed with reference to objects, goals, and methods of forecasting. Experimentation is still being performed in this

area.

Additional research is currently being performed to design an aid which will focus on Soviet crisis behavior since World War II. This aid will include the following tasks:

1. Development of an inventory of Soviet crisis management behavior, 1946-1979.

2. Collection of data on the characteristics of these crises to show the nature of Soviet military crises.

3. A more intensive analysis and coding of key Soviet crises to identify the crisis environments that may affect the occurrence of crisis management problems encountered by the Soviet Union, and variables describing crisis objectives, actions, and results for the Soviet Union.

4. Statistical analyses of the characteristics of Soviet crisis management operations, the environment in which they have taken place, and the crisis management problems encountered by the Soviet Union.

5. Comparison of these statistical analyses with earlier analyses of the same factors for the

U.S..

All of these decision aids have been advertised as being valuable to decision making. None have been experimentally evaluated with knowledgeable subjects in a decision making environment. A baseline of such evaluations is important to establish in order to provide a useful tool and better yet, to provide for much needed technology transfer and real world, real time feedback on the value (utility) of the technology.

OPINT was selected as an appropriate candidate for experimentation for a number of reasons. First, it is readily available as a package at the Naval Postgraduate School. Second, all of the equipment required for its operation already exists at the School. Finally, due to both time and monetary constraints, the procurement of other aids was unfeasible.

IV. FUNCTIONAL DESCRIPTION OF OPINT

OPINT is a decision-analytic based, computer-assisted decision strategy (Amey et al.,1979, p. 4). It was designed and built by Decisions and Designs Inc., of McLean, Virginia, under contract to the Defense Advanced Research Projects Agency (DARPA). It was written in the APL programming language for the IBM 5100 computer. In addition, OPINT has recently been rewritten in FORTRAN 4P for use on PDP 11 series computers.

The general purpose of OPINT is to aid decision makers by providing them a capability to construct, store, retrieve, exercise, and refine decision-analytic models of complex decision problems they face. The OPINT decision model, which is interactive, real-time, and on-line, is an organizing framework for information processing. Decision analysis is a methodological tool with which the decision maker defines and exercises the OPINT model to evaluate decision alternatives pertaining to the problem (Amey et al., 1979, pp. 3-21).

The OPINT system is designed to be used interactively by decision makers who are relatively unsophisticated with respect to computer technology. Accordingly, the design satisfies two human-factors objectives: OPINT is a menu-driven system and is designed to be forgiving of procedural errors by the user.

Each decision model created by the user may be given a unique label, although each is constructed using the same generic format. The model format is shown graphically in Figure 16.

The format consists of the following elements which, when completely specified, uniquely define an OPINT decision model:

1. The Decision - A short label defining the decision problem. This label is also applied to the decision model and is used to store and retrieve the model.
2. Decision Alternatives - A list of decision alternatives available to the decision maker. Each alternative is appropriately labeled.
3. An Uncertain Future Event - A key uncertain event, E, that will influence the eventual outcome of the decision. The uncertain event is attached to each of the decision alternatives.
4. Event Outcomes - A list of the discrete event outcomes, each appropriately labeled, that together define the universe of possibilities regarding the occurrence of the future event.
5. Event Probabilities - A vector of probabilities that are associated with the event outcomes, which represent the probability that an event will occur. A probability is a measure of uncertainty. It is a number between 0 and 1,

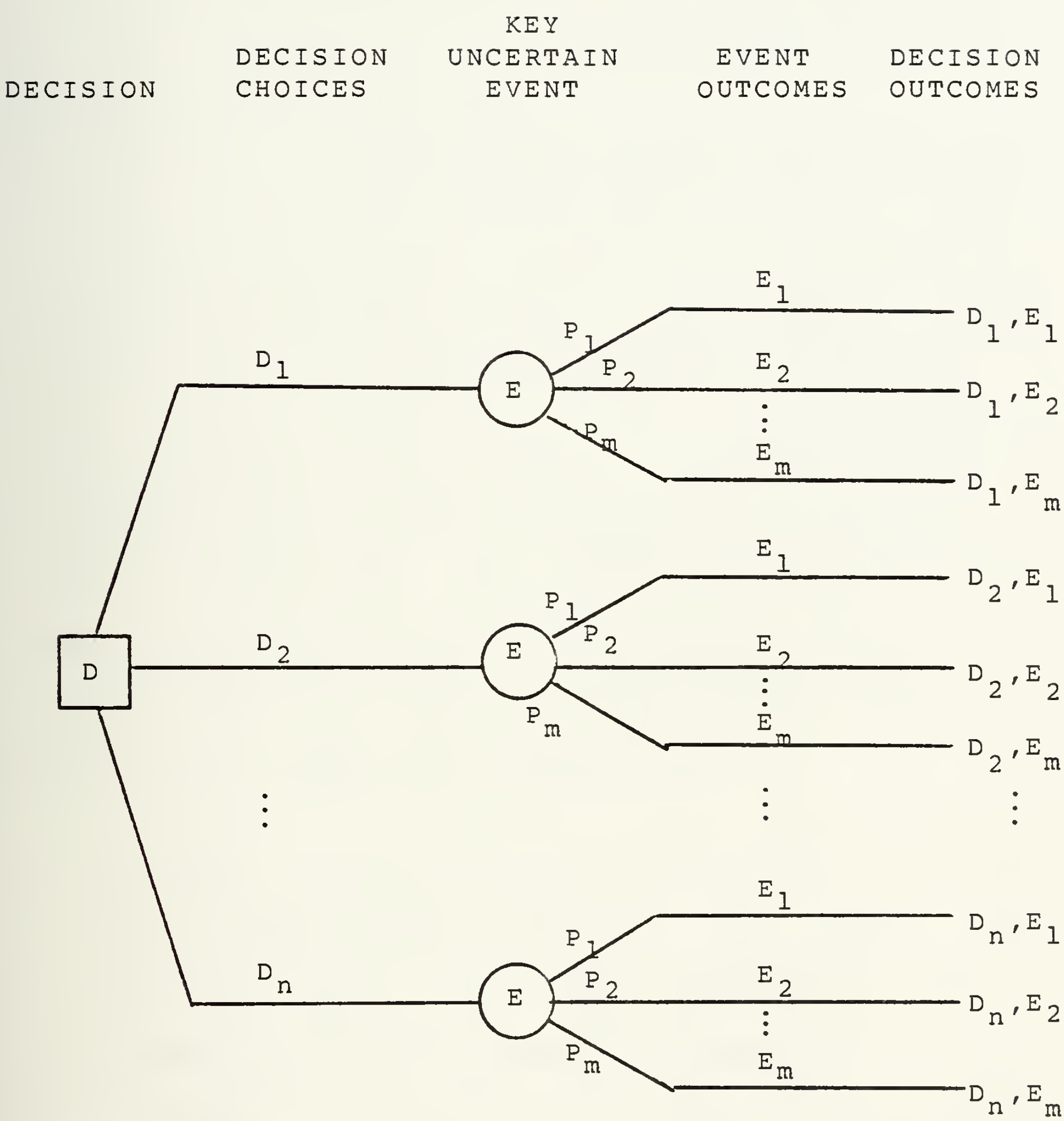


FIGURE 16: DECISION MODEL FORMAT

inclusive, that represents the extent to which an individual believes a future event will occur. However, in this specification, probabilities are expressed as a percentage of certainty, e.g., as 40% vice 0.4.

6. Decision Outcomes - The elements discussed thus far define possible decision outcomes. Each decision outcome is a paired combination of one decision alternative with one event outcome.

The remaining three elements of the model format are used to specify the relative consequences associated with the decision outcomes. The consequence of an outcome is expressed in terms of the relative regret that would be experienced by the decision maker should the outcome actually occur. These three elements are:

1. Decision Outcome Criteria - A list of criteria, each appropriately labeled, by which the decision maker would judge the relative regret associated with the decision outcome.

2. Criteria Weights - A vector of weights associated with the criteria, which represent the relative contribution of the criterion. Criteria weights are expressed numerically as a percentage of the whole, e.g., as 60%.

3. Regret - Regret is a measure of the consequence of a decision outcome. The total regret

assigned to a decision outcome is a weighted linear combination of the individual criteria regrets. For each criterion and for each decision outcome, the user must specify a value of regret. A regret is a number between 0 and -1, inclusive, that represents the relative degree of dissatisfaction that the decision maker associates with a particular decision outcome. Zero represents no regret; -1 represents maximum regret. However, in this specification regrets are always expressed as a percentage of the maximum; e.g., as -30 vice -0.3. Refer to Figure 17.

This completes the model format. The decision model is completely and uniquely specified when the elements described above are defined by the user. The input specifications describing the model can be processed to produce the following results:

1. Combined Value Regret Matrix - A single matrix that displays the total or combined regret associated with each of the decision outcomes. For each outcome, the combined regret is obtained by weighting and adding the component regrets contributed by each criteria. A combined value regret matrix is shown in Figure 18.
2. Expected Value Matrix - A single matrix that

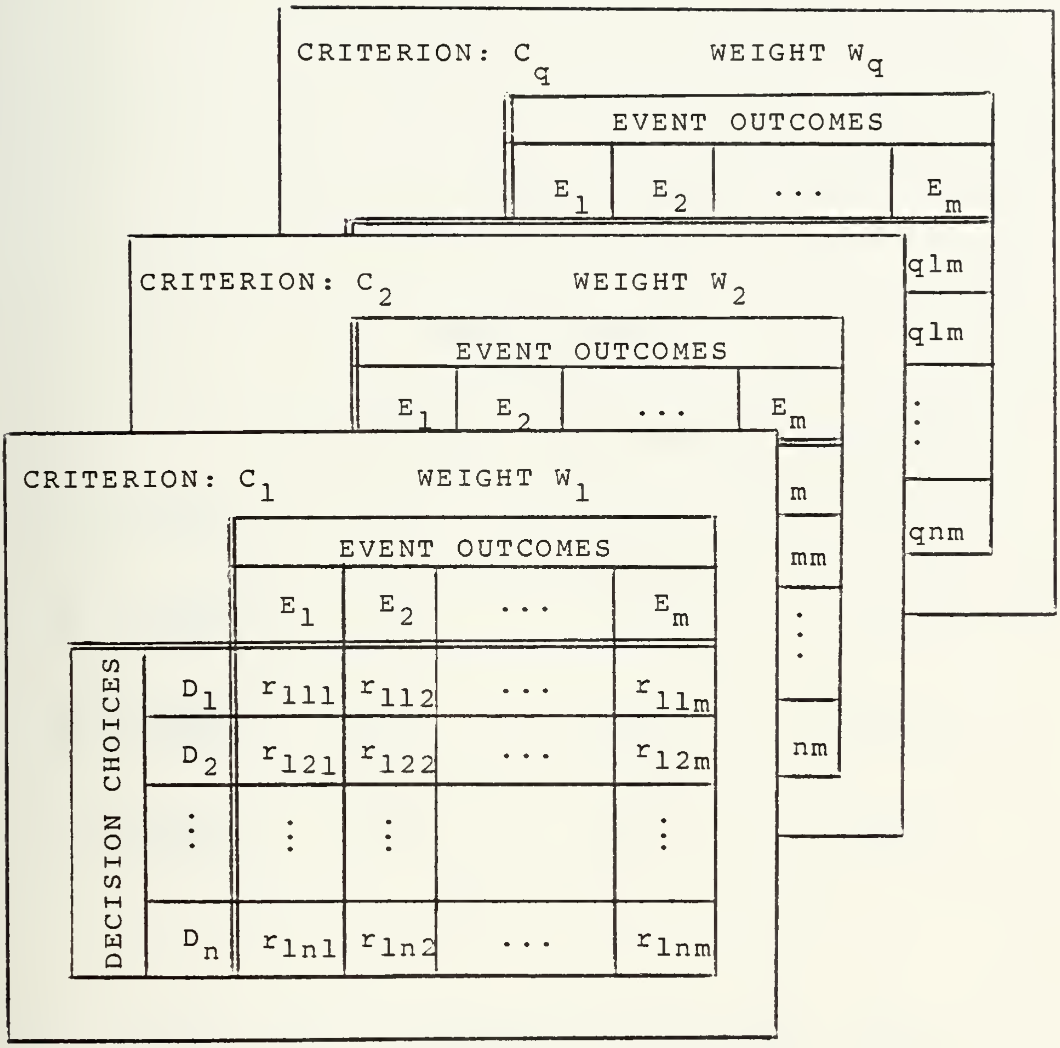


FIGURE 17: REGRET MATRICES
(Amey et al., 1979,P.9)

COMBINED VALUE

	E_1 (LABEL)	E_2 (LABEL)	E_3 (LABEL)
D_1 (LABEL)	0	-17	-31
D_2 (LABEL)	-9	-9	-17
D_3 (LABEL)	-24	-22	-22
D_4 (LABEL)	-30	-26	-26

FIGURE 18: A COMBINED VALUE REGRET MATRIX
(Amey et al., 1979, P. 10)

displays the weighted expected regret, associated with each decision outcome. The expected value matrix takes into account the relative likelihoods of the event outcomes.

3. Expected Value Vector - A vector that displays the weighted expected regret, associated with each of the decision alternatives.

The expected value matrix and the expected value vector (total) are displayed together, as shown in Figure 19.

There are two sensitivity analyses that are useful to the user. Both are based on the expected value vector and are described as follows:

1. Threshold Matrix - A matrix that displays the eleven expected value vectors generated by either one of the following operations, at the user's option:
   a. Varying the probability of a designated event outcome, from 0 to 100%, in steps of 10. The other event outcomes, maintain their proportional relationships with each other.
   b. Varying the weight of a designated criterion from 0 to 100%, in steps of 10. The weights of the other criteria maintain their proportional relationship with each other in

EXPECTED VALUE

	E_1 (LABEL)	E_2 (LABEL)	E_3 (LABEL)	TOTAL
D_1 (LABEL)	0	0	-4	-4
D_2 (LABEL)	-5	0	-2	-7
D_3 (LABEL)	-12	-1	-3	-16
D_4 (LABEL)	-15	-1	-4	-20

FIGURE 19: AN EXPECTED VALUE MATRIX AND AN EXPECTED VALUE VECTOR (Amey et al., 1979, P. 12)

the same manner as do the probabilities described in the preceding paragraph.

In both of the above cases, the least regret displayed in the expected value payoff vector is identified by an asterisk. Normally, the decision alternative that leads to the decision outcome having the least regret will change as the designated event probability or criterion weight is incremented from 0 to 100%. The points of change are referred to as threshold points and are noted on the matrix. Figure 20 shows an example threshold matrix.

EXPECTED VALUE WHEN
PROBABILITY OF E_1 (LABEL) IS:

	0	10	20	30	40	50	60	70	80	90	100
D_1 (LABEL)	-57	-52	-46	-40	-34	-29	-23*	-17*	-11*	-6*	0
D_2 (LABEL)	-51	-47	-42	-38	-34	-30	-23*	-21	-17	-13	-9
D_3 (LABEL)	-27	-27	-27*	-26*	-26*	-26*	-25	-25	-24	-24	-24
D_4 (LABEL)	-26*	-26*	-27*	-27	-27	-28	-28	-28	-29	-29	-30

FIGURE 20: A THRESHOLD MATRIX (Amey et al., 1979, P. 15)

2. Manually change event probabilities - The user may generate a test expected value vector that is based on an arbitrarily assigned vector of event probabilities. The user may specify several different probability vectors and note the resultant expected value vectors. An example of the display is shown in Figure 21.

```
                          KOREAN INTENT

                            NO ACTION   HARASS   SHOOT DOWN

CURRENT LIKELIHOOD:            60         30          10
ENTER REVISED VALUES: 30 60 10
NEW VALUES:                    30         60          10
IF THESE VALUES ARE CORRECT TYPE GO:  (GO)

                     EXPECTED VALUE/REGRET

DO NOT FLY                    -38
MODIFIED ROUTE                -26
ARMED ESCORT                  -10
HIGH PERFORMANCE A/C          -10
NORMAL MISSION                -29
```

FIGURE 21: MANUALLY CHANGED EVENT PROBABILITIES (Amey et al., 1979, P. 16)

OPINT is designed to perform the basic functions described below:

1. Maintain a library of OPINT models - Store various decision models, filed by their associated labels.

2. Load an existing OPINT model - Display the labels of those models stored in the model library, and permit the user to retrieve any desired model. The loaded model is referred to as the current model.

3. Display the results of the current model - Permit the user to examine the structure and content of the current model by displaying:

   a. event probabilities,

   b. criteria weights,

   c. regrets,

   d. combined value matrix,

   e. expected value matrix, and

   f. expected value vector.

4. Revise the current model - Permit the user to make changes to the structure and content of the current model. The user may revise:

   a. event probabilities,

   b. criteria and criteria weights,

   c. decision alternatives,

   d. regrets, and

   e. combined value regret matrix.

5. Save the current model - Permit the user to add the current model to the model library.

6. Perform sensitivity analyses - Permit the user to test the sensitivity of the current model by determining thresholds or manually changing

probabilities.

7. Create a new OPINT model - Permit the user to create a new model, which then becomes the current model. The user creates a model by specifying the elements required for the model as explained earlier. The user may also use a reference gamble to validate the assigned values of regret.

probabilities.

7. Create a new OPNET model - Permits the user to create a new models, which then becomes the current model. The user creates a model by specifying the elements required for the model as explained earlier. The user may also use a reference manual to validate the assigned values of models.

V. THE DESIGN OF THE EXPERIMENT

The conduct of experiments using command and control decision aids, such as OPINT, present special problems (Cain and Poh, 1978, p. 6). Historically, the evaluation of command and control systems has been focused on hardware measurements. Little attention was paid to software, especially decision aids. As a result, few well defined quantitative measurements exist for measuring the quality of C3 decision aids (Sinaiko, 1977, pp. 5-6). Second, there are no "correct" answers to a decision problem (Daniels, 1977, p. 16). Rather, an aid such as OPINT is a cognitive tool to assist the decision maker in revealing and formulizing the elements of the decision problem as the decision maker perceives them. Lastly, during the development of these decision aids, there has been relatively little synergism between developers and potential users (Cain and Poh, 1978, p. 6). Users are often not familiar with the new technology and are unsure exactly what to expect in the way of performance. Developers are unsure exactly what the potential users want. This occurs because they aren't sure who the users will be and causes a very general aid to be developed - one which will try to suit everyone's needs.

Any experiment which involves the use of decision aids must be designed carefully. The experiment should be

designed in order to assess both the capability of the technology and its overall utility as it relates to total system performance (Daniels, 1977, p. 14). There are four levels of experiments varying in formalism from very loose "free play" with only subjective judgment output to "highly structured" with complete specification of conduct of trials and output consisting of carefully measured system attributes (Barr et al., 1978, p. 2). These levels from least structured to most structured are:

1. Validation experiments. These experiments would consist of the debugging of hardware or software. The feasibility of the system to work according to fixed specifications is determined. An example would be the debugging of the OPINT software prior to placing it on line for operational testing or use.

2. Demonstration experiments. These experiments would be somewhat more structured than the validation experiment, in that a scenario would be followed. The term demonstration refers to the type of output from the experiment. The output would be mostly personal impressions in the minds of the users of the system under demonstration.

3. Assessment experiments. These are experiments where trials are conducted over a wide range of

conditions with little control over sources of error. The goal is to obtain an idea of how well the system performs. The output is subjective opinions of the experimenters and subjects. Their opinions of how worthwhile the system is and any potential uses are recorded as experimental data.

4. Evaluation experiments. These are the most rigorous type of experiments. Experimental conditions are carefully controlled. A number of replications are performed followed by a formal analysis of numeric measurement data.

The assessment experiment was chosen as the means for determining the utility of OPINT. No prior experiments concerning the utility of OPINT have been performed and therefore no baseline currently exists. The results of this experiment should fill that gap. Subjective impressions and judgments of C3 users are what is needed to help determine the usefulness of OPINT and that is what this assessment will do.

The major objective of this experiment was to assess the utility of OPINT as a computerized decision aid in C3 applications. Secondary objectives which helped in this goal included the following:

1. To assess the extent to which OPINT facilitates thorough and timely decision making.

2. To investigate the user-OPINT interface and to suggest remedial measures or alternate designs as appropriate.

3. To survey user opinion on the operation and potential usefulness of OPINT in C3 decisions.

The primary objective of OPINT is to assist decision makers in the structuring and analysis of decision problems (Amey et al., 1979, p. 4). One could imply from this that a better decision or product is delivered through the use of OPINT. The question which is now immediate is, "What is better?" Better can not be scenario dependent or player dependent. It must be general in nature. OPINT's performance may be be measured in terms of time (the time from perception of problem to decision). A faster decision is often times needed and therefore the capability to do so may be termed "good to have". But it is only "good to have" if the quality of the decision remains at least as good as without the aid. In order to assess this feature, a method for measuring the quality of the decision is needed. As stated earlier, the "correctness" of a decision is extremely difficult to measure if at all. In this experiment no attempt was made to define or measure this attribute.

What remained was the subjective judgment of the subjects involved in the experiment. The subjects were students from the C3 curriculum at the Naval Postgraduate School. C3 students were used since the assessment was

performed of OPINT's ability to help with C3 type problems. These students were all operational officers with a large amount of experience in operational problems in the field. They represented the Army, Air Force, Navy, and Marines. They were in their last (sixth) quarter of studies and had been exposed to numerous decision models and aids. The subjects were grouped into pairs to form a decision team. All the subjects had been trained in the theory and operation of OPINT and had received at least three hours of instruction including one hour of hands-on time.

Two types of decision situations were used - time critical and time not critical. It was understood that the range of time possibilities is infinite and there was no way to assess each. Therefore, the two extremes that could be encountered were used.

Two scenarios were followed which required the subjects, acting as decision makers, to recommend a specific course of action. The two scenarios represented varying complexities which face a C3 decision maker. They were carefully designed to avoid the allegation that they were either OPINT or subject dependent. The first scenario, a Cuban blockade problem, was rather complex. It required an in-depth assessment of intelligence estimates in order to predict the occurrence of an uncertain event. In addition, the evaluation of numerous courses of action was required. The second scenario was an air reconnaissance problem. This one was somewhat easier as the key uncer-

tain event had already been assessed and the decision maker was only required to evaluate the courses of action which were available. A copy of each scenario is included in Appendix B.

The subjects played one scenario using OPINT and then played the second in a manual mode without the use of OPINT. The schedule was varied so some subjects played the difficult Cuban problem first and some the easier reconnaissance problem. In addition, the use of OPINT was varied so it was used alternately first or second. Figure 22 portrays a typical schedule. Notice the added dimension of the time critical and time not critical factors.

It was recognized the evaluation measures used in the experiment would not be quantitatively measurable. Therefore care was taken to carefully select both measures of effectiveness (MOE) and measures of performance (MOP) which supported the goals of the experiment.

A measure of effectiveness is defined as those evaluation measures which indicate the contribution of OPINT to the overall decision process (ACCAT Operational Evaluation Task, 1978, p. 6). Measures of performance are defined as those evaluation measures which indicate a level of technical performance relative to the internal functioning of OPINT itself. Both are applicable to decision aid experiments. The MOE's and MOP's were designed so as to:

1. Measure the contribution of OPINT to the

TIME NOT CRITICAL

	OPINT	MANUAL
CUBAN SCENARIO	TEAM 1(FIRST) TEAM 4(SECOND)	TEAM 2(FIRST) TEAM 3(SECOND)
RECON SCENARIO	TEAM 2(SECOND) TEAM 3(FIRST)	TEAM 1(SECOND) TEAM 4(FIRST)

TIME CRITICAL

	OPINT	MANUAL
CUBAN SCENARIO	TEAM 5(FIRST) TEAM 7(SECOND)	TEAM 6(FIRST) TEAM 8(SECOND)
RECON SCENARIO	TEAM 6(SECOND) TEAM 8(FIRST)	TEAM 5(SECOND) TEAM 7(FIRST)

FIGURE 22: EXPERIMENT SCHEDULE

decision process, not the decision outcome.

2. Be objective so they do not introduce bias.

3. Be simple, to achieve economy and ease of use.

4. Permit determination of which functions within the decision process are aided and under what conditions.

5. Yield results in the experiment which are extendible to real world operational environments.

6. Be operationally plausible and intuitively understandable by potential users (ACCAT Operational Evaluation Task, 1978, pp. 8-9).

The following is a list of the MOE's which were chosen for use in the experiment:

1. Time elapsed in arriving at the decision. This includes the time from perception of a problem until a decision is reached. In addition, the time elapsed in the actual use of the aid will be measured.

2. Identification/elimination of non-essential information.

3. Objectivity in determining relationships among factors contributing to the selection of an

alternative course of action.

4. Risk perceived to be associated with the decision.

5. Ease of use of the decision aid.

6. Ease of modification of data within the model.

7. Perceived advantages/disadvantages gained from the use of the decision aid.

8. Ease of recovery from user errors.

Data was gathered on each of the above, through the use of questionnaires. The exception was the first MOE. For this one, times were recorded while the subjects were using OPINT to capture the amount of time required to build the model, time to evaluate the data, and total time to decision. These times were then compared with times to evaluate data and total time for the manual operation. Three questionnaires were used to record the opinions of the subjects. A questionnaire was completed after the play of each scenario and one completed after both. Sample questionnaires are included as Appendix C.

During the actual play of the scenarios, a consideration was how to satisfactorily place the subjects into the mental role required. This included the ability of the subjects to adequately assess probabilities of future events and the regrets required in the construction of the

model. This research design subsumed this consideration by locating probability estimates within the scenarios and defining the goals and objectives to be reached. Subjects were encouraged to provide their own regret assessments if they had experience in similar problems. If the subjects had no previous experience, an individual was available to act as a senior official. The senior official's role was to provide regret data, if needed, and to answer questions concerning uncertainties or ambiguities.

VI. THE RESULTS OF THE EXPERIMENT

Three significant results from the experiment were revealed. First, nearly all (85%) subjects stated they liked the capabilities which OPINT gave them and would use OPINT in the future if it was available to them. Second, although they liked the capabilities of OPINT, all (100%) stated they did not like it in its present form, particularly in the area of user-interface. Finally, a programming bug (error) was discovered in the use of the sensitivity analysis. The sensitivity analysis permitted the comparison of only three courses of action, showing the expected regrets for the others as zeros.

It is important to keep each of these results in mind as the specific results are read. Many negative comments were conditioned by the statement that if user-interface was better, or if the sensitivity worked correctly, the comments would be positive. The cases where this occurs are appropriately noted.

The sensitivity analysis programming "bug" was found during the play of the Air Reconnaissance Scenario. This scenario had five possible courses of action which needed evaluation. OPINT handled the expected value and combined value calculations perfectly. But whenever a sensitivity analysis was asked for, OPINT would not compute the expected regret for all courses of action. Additional research

revealed that in the case of a sensitivity analysis where the probability of the event was varied, OPINT would only compute three courses of action. When the variation of the criterion weights was asked for, OPINT would compute four courses of action. Any remaining courses of action received regret values of zero. This did not permit a complete evaluation of alternatives and had an adverse effect on the feelings of the subjects toward the decision aid. Although OPINT had only been installed on the PDP 11/70 for one month prior to the experiment, programming bugs such as these should have been detected and corrected prior to presenting the aid as operationally ready.

All but four subjects said they felt the scenarios were realistic. These four felt that priorities established in the scenario were not what they felt they should be and that prior decisions made did not seem realistic from their viewpoint. The use of the realistic scenarios coupled with the ability of the subjects to input their own probabilities and regrets facilitated a decision making environment that was as realistic as possible.

The eight MOE's stated in Chapter Five were evaluated through the use of questionnaires. A summary of the results for each is shown below:

1. Time elapsed in arriving at the decision. Times were recorded in order to capture the time subjects were spending on the scenarios, both with and without the utilization of OPINT.

These times were recorded not to determine if a faster decision was being made, but to provide an indication of how long it took to build the OPINT model and evaluate it. In all cases, more time was spent while using OPINT than in the manual state. The time required to build the OPINT model averaged 45 minutes for the Cuban scenario and 25 minutes for the Air Reconnaissance scenario. The times were tightly grouped as is shown by standard deviations of 4 and 2 minutes respectively. The time to evaluate THE OPINT model averaged 21 minutes and 14 minutes. Again small standard deviations of 3 and 1 minute show tightly grouped data. These times are very near to what was expected and show a general ability of the subjects to build and manipulate the model.

2. Identification/elimination of non-essential information. The goal here was to determine if the decision process was aided by identifying non-essential information. 63% of the users of OPINT were able to identify some non-essential information while only 31% were able to in the manual mode. The items of information identified varied according to subject-specified probabilities and regrets. An additional 44% of the OPINT users stated problems with the

sensitivity analysis prevented them from possibly identifying any non-essential information.

3. Objectivity in determining relationships among factors contributing to the selection of a course of action. The goal of this MOE was to determine if the subjects were aided in the decision process by determination of which factors were the most critical. 63% felt OPINT definitely aided in the decision process. These subjects definitely liked the way OPINT promoted detailed and non-subjective analysis of what was going to happen and why. The rest found it confusing due to uncertainty of what the displays were actually telling them. 63% also stated they were able to assess the criticality of the contributing factors when using OPINT. The evaluator's observation here was that in the manual mode, one factor was determined to be critical and then the rest ignored. This did not occur when OPINT was used.

4. Risk perceived to be associated with the decision. This MOE was used to measure the degree of uncertainty or certainty in the final decision. 85% of the subjects in the manual mode said they made the best decision possible

while only 56% in the OPINT mode felt that certain. Two types of comments were made. First, the sensitivity problem was again mentioned as a hindrance. Second, several subjects felt uneasy about what the numbers in the displays actually meant. For example, in the expected value, combined value, and sensitivity displays, only numbers are shown. There is no explanation of what they mean or which numbers are best.

5. Ease of use of the decision aid. This MOE was used to help determine what type of user-OPINT interface existed. Only 31% stated that OPINT presented displays in a manner which was easily understood. Sensitivity and combined value displays received the most comments as being the most difficult to understand. Also, there were several comments concerning the inputs required. Many were not sure what was actually being asked for and when to hit the carriage return and when not to. Almost all 85% stated the displays were generated quickly enough. No problems were observed here, even during times of peak usage. Additional comments concerned the use of menus. More efficient movement through the menu levels was wanted.

6. Ease of modification of data within the model. The goal here was to determine how easy it was to correct the many errors that untrained typists will make. 85% stated it was easy to make corrections in the model. The only negative comments concerned the use of the menus for this purpose. There existed too much retracing through menu selections to make corrections in the same area or level of the model.

7. Ease of recovery from user errors. This MOE measured how well the OPINT program recovered from input errors. Here the goal was to determine if normal typing or careless errors caused major problems. 92% of the subjects who made errors felt recovery from these errors was poor. Comments centered around some simple mistakes which caused major problems. During initial displays, a selection of a choice is made by moving the cursor to the desired choice and then hitting the 'X' key for execution. However in six cases, subjects pressed the 'X' key followed by a carriage return. This caused the program to halt and the subjects were required to begin again. Several subjects felt that nebulous input directions caused several errors which could not be changed until after

the entire model was completed.

8. Perceived advantages/disadvantages gained from the use of OPINT. The explicit consideration of all factors through the promotion of a good thought process was the comment most often stated. Several stated they liked being forced into a logical thought process. Also, the subjects felt that OPINT provided them with documentation of their decision and would make it easier to present the outcome and justify the conclusion. The disadvantages listed for using OPINT as it currently exists centered around the user-interface problem. There existed a general lack of comfort due to the limited descriptions and assistance from the aid.

9. An additional question concerning training was asked of each subject. They were asked to comment on the amount of training they felt was required for OPINT usage. The overwhelming response was about two hours of structured instruction on the theory and use of the aid, followed by one to two hours of hands-on demonstrations. This amount of instruction was exactly what each subject received prior to the experiment.

VII. CONCLUSIONS AND RECOMMENDATIONS

It was determined that OPINT is beneficial to the decision maker in the decision making process. The majority of the subjects comments were either positive in relation to OPINT or would have been with either no program errors or better user-interface. OPINT's greatest advantage lies in two areas. First, it promotes (and possibly even forces) the user into a sound thought process. In the heat of crisis or even just day-to-day decisions, it is often too easy to forget the principles of good decision making and slip to something less. The use of OPINT could help to keep that from happening. Second, OPINT provides its own documentation. This documentation is then available to present decisions and show why a particular decision was made. It is also easy to focus on the critical areas and not waste time on the non-important ones.

There are still some major flaws which need to be worked out of the system. The first and foremost is the sensitivity analysis. Program bugs such as these can not exist in an aid if it is to be used properly. Second, is the user-interface problem. The aid must be designed for the casual user, one who at one time may have been proficient, but through lack of use has forgotten the key requirements. Additional comments concerning what is needed or what is being displayed are a must.

The movement of the user through the aid via the menus also needs attention. Users should be given the choice of returning to several levels rather than only up one or down one.

The final and by no means the least important is the problem of program halts. Nothing grieves a user more than having to start over, especially after a great deal of work has already been done. The system currently displays numeric inputs for verification. There is no reason why alphabetic or menu choices could not also be done.

This author has several recommendations for both improving the decision aid and for future experiments with it. As stated earlier, the aid needs to be designed for the optional user. This user's knowledge of the aid could range from complete to nothing depending on amount of usage. The aid should be designed for the two extremes and even for the user in the middle. It needs to be both user friendly" and "error tolerant". One technique could be optional verbosity. For each display, three sets of comments could be prepared. The decision maker then selects which set is desired depending on need. The knowledgeable user would receive only short phrases which could be keyed on to generate inputs or display results. The same type of capability would exist for the other types of users. This way the user receives only what is needed. Another variation of this is to allow each user to specify exactly what comments are needed to insure correct usage and

interpretation.

The addition of some sort of "HELP" command would also be useful. If a decision maker gets stuck and needs some prompting or interpretation, a simple request would fill that need. User confidence could improve greatly with this simple addition.

Once OPINT is redesigned to meet the needs of the users, as stated in the results, additional experiments should be conducted to measure additional capabilities of the aid. This experiment did not consider whether a better decision was being made. This is not an easy problem and further research and experimentation is called for.

Another area for experimentation has to do with the area of regret values. OPINT currently is designed to handle regrets rather than gains. Some subjects casually stated they might have preferred to use gains rather than regrets. Additional experiments to determine if the use of gains vice regrets has an impact on user efficiency is definitely called for.

Finally, thought should be given to providing a hard copy option to users who have only a soft copy (CRT) capability. Further experimentation could be done to determine if potential users want or even need a hard copy capability.

The underlying premise of these results is that most of the trouble encountered in getting computers used in decision making comes from too much emphasis on bits and

bytes and minimal attention on the user. The use of decision support systems such as OPINT, offer an opportunity that is both trivial and immense. It is immense in that they can embed the computer in decision making activities where large payoffs could be provided and trivial in that they represent no major advance in technology. Building innovative systems will be a difficult and risky venture for some time to come. The future of decision support systems and operational decision aids depends on some adjustments that both the developers and users must make. But these adjustments are small ones, and are mainly attitudinal. Little new knowledge is required. But the opportunities are all substantial, and the personal and organizational rewards high.

APPENDIX A - SAMPLE OPINT SESSION

```
% opint

 1) Ann Arbor
 2) Any hardcopy
 3) ADM 3A
Which terminal type are you using? 2

Please select one of the following options.
OPTION
   1     Display results
   2     Edit model
   3     Sensitivity
   4     Load model
   5     Create or add to model
   6     Save model
   7     New information
   8     End session
Enter desired option:5

Is this a new model?(y or n):y

Please enter a title for this model: [air reconnaissance  ]

Which portion of the model would you like to create?
OPTION
   1     Generate influence diagram
   2     Generate value/regret model
   3     Add Baysian indicators
   4     Return to main menu
Enter desired option:1

 What is the main event of interest? [korean intent   ]
  korean intent
  ---------------
      !  !
      !  !- [                  ]

Please enter the outcome labels for the event you have
called korean intent

Enter outcome label: [no action ]
Enter outcome label: [harassment]
Enter outcome label: [shoot sown]
Enter outcome label: [          ]
```

```
Please enter the orobaoilty of each outcome of the
event you have labeled korean intent

                            no action harassmentshoot down
                              -60 30 10 --------  --------
Normalized values:                 o0.0        30.0       10.0
If these values are correct type go: [go]

which portion of the model would you like to create?
OPTION
   1     Generate influence diagram
   2     Generate value/regret model
   3     Add Baysian indicators
   4     Return to main menu
Enter desired option:2

You will be asked to provide the criterion to be used
in your value judgement, the actions you may take, and
the associated value/regret matrices for each criterion.
Please press return to continue.

Enter the names for each of your criterion:

Criterion: [aircraft-aircrew    ]
Criterion: [loss of information ]
Criterion: [national influence  ]
Criterion: [recon program       ]
Criterion: [                    ]

Now enter the labels for each action.
Action: [do not fly     ]
Action: [modified route ]
Action: [armed escort   ]
Action: [high perf a/c  ]
Action: [normal mission ]
Action: [               ]

You will now be asked to provide the values for
each of these value matrices.
Please press return to continue.

          Please enter regret/value matrix for
            aircraft-aircrew
                no action harassmentshoot down
do not fly         0 0 0--  --------  --------
do not fly              0.0        0.0        0.0
If these values are correct type go: [go]
```

```
modified route      0 -20 -60--------  --------
modified route            0.0        -20.0       -60.0
If these values are correct type go: [go]

armed escort        0 -15 -35--------  --------
armed escort              0.0        -15.0       -35.0
If these values are correct type go: [go]

high perf a/c       0 -5 -15 --------  --------
high perf a/c             0.0         -5.0       -15.0
If these values are correct type go: [go]

normal mission      0 -25 -100-------  --------
normal mission            0.0        -25.0      -100.0
If these values are correct type go: [go]


          Please enter regret/value matrix for
            current information
                no action harassmentshoot down
do not fly          -100 -100 -100---  --------
do not fly             -100.0      -100.0     -100.0
If these values are correct type go: [go]

modified route      -30 -30 -30------  --------
modified route           -30.0       -30.0       -30.0
If these values are correct type go: [go]

armed escort        -5 -5 -5 --------  --------
armed escort              -5.0        -5.0        -5.0
If these values are correct type go: [go]

high perf a/c       -50 -50 -50------  --------
high perf a/c            -50.0       -50.0       -50.0
If these values are correct type go: [go]

normal mission      0 0 -100 --------  --------
normal mission            0.0          0.0      -100.0
If these values are correct type go: [go]

          Please enter regret/value matrix for
            national influence
                no action harassmentshoot down
do not fly          -50 -100 -70-----  --------
do not fly               -50.0      -100.0       -70.0
If these values are correct type go: [go]

modified route      -20 -20 -50------  --------
modified route           -20.0       -20.0       -50.0
If these values are correct type go: [go]
```

```
armed escort        -40 0 0  --------  --------
armed escort            -40.0        0.0         0.0
If these values are correct type go: [go]

high perf a/c       -25 -10 -10------  --------
high perf a/c           -25.0       -10.0       -10.0
If these values are correct type go: [go]

normal mission      0 -25 -100-------  --------
normal mission            0.0       -25.0      -100.0
If these values are correct type go: [go]


         Please enter regret/value matrix for
           reconnaissance prog
               no action harassmentshoot down
do not fly          -100 -100 -100---  --------
do not fly             -100.0      -100.0      -100.0
If these values are correct type go: [go]

modified route      -70 -50 -50------  --------
modified route          -70.0       -50.0       -50.0
If these values are correct type go: [go]

armed escort        0 0 0--  --------  --------
armed escort              0.0         0.0         0.0
If these values are correct type go: [go]

high perf a/c       -10 -10 -10------  --------
high perf a/c           -10.0       -10.0       -10.0
If these values are correct type go: [go]

normal mission      -10 -70 -80------  --------
normal mission          -10.0       -70.0       -80.0
If these values are correct type go: [go]

Please enter a set of importance weights for these criterion.
aircraft-aircrew
current information
national influence
reconnaissance prog
wts:     100 10 30 30---- -----
Norm:    58.8   5.9  17.6  17.6
If these values are correct type go: [go]

which portion of the model would you like to create?
OPTION
   1     Generate influence diagram
   2     Generate value/regret model
   3     Add Baysian indicators
   4     Return to main menu
Enter desired option:4
```

```
Please select one of the following options.
OPTION
    1     Display results
    2     Edit model
    3     Sensitivity
    4     Load model
    5     Create or add to model
    6     Save model
    7     New information
    8     End session
Enter desired option:1

The following displays are available
OPTION
    1     Expected value
    2     Combined value
    3     Event likelihood
    4     Values
    5     Value weights
    6     Influence diagram
    7     Return to main menu
Enter desired option:1

     Expected value/regret
do not fly              -35.4
modified route          -23.8
armed escort             -9.2
high perf a/c            -9.8
normal mission          -20.1
Please press return to continue.

The following displays are available
OPTION
    1     Expected value
    2     Combined value
    3     Event likelihood
    4     Values
    5     Value weights
    6     Influence diagram
    7     Return to main menu
Enter desired option:2

          Combined Value
                  no action harassmentshoot down
do not fly              -32.4      -41.2      -35.9
modified route          -17.6      -25.9      -54.7
armed escort             -7.4       -9.1      -20.9
high perf a/c            -9.1       -9.4      -15.3
normal mission           -1.8      -31.5      -96.5
Please press return to continue.
```

The following displays are available
OPTION
1 Expected value
2 Combined value
3 Event likelihood
4 Values
5 Value weights
6 Influence diagram
7 Return to main menu
Enter desired option:7

Please select one of the following options.
OPTION
1 Display results
2 Edit model
3 Sensitivity
4 Load model
5 Create or add to model
6 Save model
7 New information
8 End session
Enter desired option:3

Select one of the following:
OPTION
1 Event probability thresholds
2 Value weight thresholds
3 Return to main menu
Enter desired option:1

Which event outcome likelihood should be varied?
OPTION
1 no action
2 harassment
3 shoot down
Enter desired option:1

Expected Value when
Probability of no action is:

	0	10	20	30	40	50	60	70	80	90	100
do not fly	-39	-38	-37	-37	-36	-35	-34	-34	-33	-32	-31
modified route	-32	-31	-29	-27	-26	-24	-23	-21	-20	-18	-17
armed escort	-11	-11	-10*	-10*	-9*	-9*	-8*	-8*	-7*	-7	-6
high perf a/c	-10*	-10*	-10*	-10*	-10	-10	-10	-10	-9	-9	-9
normal mission	-42	-38	-34	-30	-26	-22	-18	-14	-10	-6*	-2*

Please press return to continue.

Select one of the following:
OPTION
1 Event probability thresholds
2 Value weight thresholds

```
   3     Return to main menu
Enter desired option:3

Please select one of the following options.
OPTION
   1     Display results
   2     Edit model
   3     Sensitivity
   4     Load model
   5     Create or add to model
   6     Save model
   7     New information
   8     End session
Enter desired option:6


Please select one of the following options.
OPTION
   1     Display results
   2     Edit model
   3     Sensitivity
   4     Load model
   5     Create or add to model
   6     Save model
   7     New information
   8     End session
Enter desired option:8
```

APPENDIX B - SAMPLE SCENARIOS

CUBAN BLOCKADE SCENARIO

On 25 March 1980, photographs received from military surveillance aircraft showed the existence of new construction along the southern coast of Cuba. Intelligence analysts believe the construction to be a new major Soviet nuclear submarine support base. However, they are undecided as to whether it will be capable of resupplying only nuclear fuel or both nuclear fuel and nuclear SLBM missiles.

Additional intelligence from other sources has revealed the presence of hundreds of new technicians in the area. In response to American inquiries, the Soviets have stated that they are merely helping the Cubans build a new merchant port. They claim the technicians will leave as soon as the port is completed.

Most US observers are highly concerned over these new developments. They feel the presense of a new port, capable of nuclear retrofit for Soviet submarines, has a serious impact on US national security. No longer would the Soviet submarines be required to return to home ports. They could conceivably patrol near our shores for unlimited periods of time. If a nuclear war ever did break out, a missile resupply base so near-by could be devastating.

Analysts believe the new construction is caused by the possibility of non-ratification of the new SALT Treaty. They feel if the Treaty is not ratified, the Soviets will

have a jump in arms escalation and the US will have no power to interfere. The analysts also believe that if the Treaty is ratified, the construction will quickly cease.

On the morning of 27 March, three Soviet ships were detected sailing towards Cuba. Reconnaissance has revealed one to be a freighter, one an armed escort destroyer, and the last an escort submarine. Intelligence sources in the Soviet Union have said the freighter is carrying the first supply of nuclear fuel and may possibly be also carrying SLBM's.

Fears that the Soviets may be trying to quickly establish a stronghold in Cuba prompted the President to order a three ship Task Force to intercept the Soviet freighter. The mission of the Task Force is to determine if nuclear supplies of any type are on board, and if so, to detain it awaiting further instructions.

The Soviets immediately responded by stating they would absolutely deny any boarding of the freighter and any such action would be met by military retaliation. Intelligence has also revealed the ordering of at least ten Soviet submarines into the area and the rapid augmentation of its Atlantic Force.

The President has decided he can not allow nuclear supplies to reach Cuba and he feels a blockade of some type must be placed around Cuba. He immediately placed the Atlantic Fleet on alert and ordered them to begin steaming towards Cuba. In addition, he also placed the Mediterranean

Fleet on alert.

The type and size of blockade has not yet been determined. The President has asked you for your recommendation. The President specifically wants a recommendation as to whether a total blockade of all shipping, a modified blockade of some sort allowing merchant ships carrying non-military cargo to pass, or a roving patrol which would only detain ships carrying military hardware.

Operations personnel have stated it would require the entire Atlantic Fleet and half of the Mediterranean Fleet to invoke a total blockade. A modified blockade would require only the Atlantic Fleet while the roving patrol would only need half of the Atlantic Fleet resources.

Intelligence analysts are unsure what the Soviet intentions will be concerning the situation. They believe their options to be one of three:

1. An attack of the blockading forces.

2. An attempt to run through the blockade without initiating any aggression, or

3. Submission to the blockade. This means the Soviets may relent to having some ships searched but may have others return directly home.

They agree, however, that two upcoming events will help to determine their motives. The impending vote on

the SALT Treaty and final determination of exactly what type of construction is being done on the coast are the key issues in assessing their intentions. In addition, they feel the SALT Treaty vote will be effected by both US public opinion concerning the Treaty and current world opinion concerning the situation. The UN Security council is scheduled to meet in two days to discuss the situation.

The analysts have assessed the probability of US public opinion being pro-SALT as 70% and anti-SALT as being 30%. World opinion is assessed as having a 40% chance of being pro-US, 30% pro-Soviet, and 30% of being neutral. The analysts also currently agree to a 60% likelihood of the construction being to support full nuclear resupply, 30% for only Naval resupply (non-armaments), and 10% as a new commercial port.

The items the President wants considered in the selection of a best course of action are (in order of importance):

1) National security. The president feels he can not allow the Soviets to establish a supply base in Cuba.

2) Safety of US Nationals currently in Cuba. The US has recently begun exporting numerous commercial products to Cuba in an effort to boost a sagging economy. At present, it is estimated there are at least 2000 Americans in

Cuba.

3) US public opinion. This is an election year and analysts feel there will be public outcry if we force the Soviets into a military confrontation, but the public will be impressed by strong measures which force the Soviets into accepting our demands.

4) Cuban reaction. The US has only recently begun trade with Cuba and is anxious to continue this if at all possible. Any type of blockade imposed around Cuba will have a serious impact on these trade agreements.

5) World opinion. Any confrontation between the US and USSR is undesirable. If the US is successful with the blockade, world opinion will be high. However, if we provoke aggression by our actions, we will lose additional world support which is desperately being sought by the President.

AIR RECONNAISSANCE SCENARIO

On 5 March 1980, an unarmed Mohawk reconnaissance aircraft aborted its mission over Korea. It returned to its base where the crew reported an interception by a fighter-type aircraft from North Korea. The crew of the unarmed Mohawk had not stayed around long enough to determine whether the intercepter was there to harass, shoot, identify, or had just "happened along" while on a routine training flight. Another reconnaissance flight is scheduled for tomorrow and the commander needs a recommendation concerning future flights.

After further discussion, the commander desires the following options evaluated in light of what has happened and what the intelligence staff conclude are North Korea's intentions:

1. Do not fly into the area anymore.

2. Fly into the area on a modified route. This modified route would be less sensitive but also less productive in collection potential.

3. Fly into the same area but now with an armed escort.

4. Fly into the area with high-performance aircraft. The aircraft would be less vulnerable but would not collect data as well as the normal aircraft.

5. Fly a normal mission; do not change anything from previous flights.

The commander is mostly concerned with the possible loss of the aircraft and crew during the mission. However, he is also concerned with the loss of prestige or political influence if flights were stopped or altered. The loss of information and the possible impact n the reconnaissance program in other areas are also important factors.

The intelligence section believes it has assessed the possible intentions of the North Korean Government on future flights. Based on past situations and current capabilities, they feel there is only a slim chance (10%) the Koreans will try to shoot future aircraft down, a moderate chance (30%) they will harass, but probably will do nothing (60%).

APPENDIX C - SAMPLE QUESTIONNAIRES

QUESTIONNAIRE FOR TEAM MEMBERS WITHOUT OPINT

NAME:

RANK:

TEAM # :

SCENARIO:

WHAT WAS YOUR RECOMMENDED ACTION?

WHY DID YOU RECOMMEND THAT ACTION?

PLEASE ANSWER THE FOLLOWING QUESTIONS AS INDICATED.

1. Do you feel this scenario was realistic? If no, please comment in the space provided.

   a. Yes

   b. No

2. Were you able to identify any non-essential information during your evaluation of the courses of action? If yes, what was that information?

   a. Yes

   b. No

3. Were you able to assess the criticality of the factors which contributed to the choice of the recommended course of action? If yes, which factors were the most critical?

   a. Yes

   b. No

4. Do you feel confident that your recommendation was the "best", based on the information provided? If no, why not?

   a. Yes

   b. No

QUESTIONNAIRE FOR TEAM MEMBERS WITH OPINT

NAME:

RANK:

TEAM #:

SCENARIO:

WHAT WAS YOUR RECOMMENDED ACTION?

WHY DID YOU RECOMMEND THAT ACTION?

PLEASE ANSWER THE FOLLOWING QUESTIONS AS INDICATED.

1. Do you feel this scenario was realistic? If no, please comment in the space provided.

   a. Yes

   b. No

2. Were you able to identify any non-essential information during your evaluation of the courses of action? If yes, what was that information?

   a. Yes

   b. No

3. Were you able to assess the criticality of the factors which contributed to the choice of the recommended course of action? If yes, which factors were the most critical?

   a. Yes

   b. No

4. Do you feel confident that your recommendation was the "best", based on the information provided? If no, why not?

   a. Yes

   b. No

5. Did OPINT present the evaluated data in a manner which was easily understood? If no, which displays were difficult to understand?

a. Yes

b. No

6. Did OPINT display its results quickly enough? If not, which displays were slow?

a. Yes

b. No

7. Was it easy to make corrections in the model? If not, comment on your problems.

a. Yes

b. No

8. Did OPINT recover well from any errors you might have made? If not, what was the result?

a. Yes

b. No

c. N/A - I did not make any errors.

5. Did OPINT present the evaluation data in a format which was easily understood? If not, which displays were difficult to understand?

a. Yes

b. No

6. Did OPINT display the results/menus quickly enough? If not, which displays were slow?

a. Yes

b. No

7. Was it easy to find information in the manual? If not, comment on your problems.

a. Yes

b. No

8. Did OPINT respond well to any errors you might have made? If not, what was the result?

a. Yes

b. No

c. N/A - I did not make any errors.

QUESTIONNAIRE FOR TEAM MEMBERS AFTER COMPLETING BOTH SCENARIOS

NAME:

RANK:

TEAM # :

PLEASE ANSWER THE FOLLOWING QUESTIONS AS INDICATED.

1. To what extent did OPINT aid in your assessment of what event was going to happen?

   a. Confused

   b. No help

   c. Reinforced own ideas

   d. Clarified

   e. Enlightened

   f. Had no need to assess an event

2. To what extent did OPINT aid in your decision process for selecting a course of action?

   a. Ignored

   b. Relied upon it

   c. Added confidence

   d. Was confusing

3. Do you think that OPINT helped to speed up the decision making process?

   a. Yes

   b. No

4. Do you think you would have performed better with or without OPINT?

   a. With

   b. Without

QUESTIONNAIRE FOR TEAM MEMBERS AFTER COMPLETION WITH SCENARIO

NAME:

RANK:

TEAM #:

PLEASE ANSWER THE FOLLOWING QUESTIONS AS INDICATED.

1. To what extent did [illegible] aid in your assessment of what event was going to happen?

   a. Confused

   b. No help

   c. Reinforced own ideas

   d. Clarified

   e. Enlightened

   f. Had no need to assess an event

2. To what extent has [illegible] aided in your decision process for selecting a course of action?

   a. Ignored

   b. Relied upon it

   c. Added confidence

   d. Was confusing

3. Do you think [illegible] aids in the decision making process?

   a. Yes

   b. No

4. Do you think you would have reached a decision without [illegible]?

   a. With

   b. Without

5. Do you feel that OPINT could be improved upon? If yes, in which areas?

a. Yes

b. No

6. Do you feel decision makers should use OPINT, or should it be left to technical experts?

a. Decision makers

b. Technical experts

7. What do you perceive as being the greatest advantage in using OPINT?

8. What do you perceive as being the greatest disadvantage in using OPINT?

9. Would you use OPINT in the future if it was made available to you? Please comment.

. Do you feel that OPINT could be improved? If so, in which areas?

a. Yes

b. No

. Do you feel decision makers should use OPINT, or should it be left to technical experts?

a. Decision makers

b. Technical experts

. What do you perceive as being the greatest advantage in using OPINT?

. What do you perceive as being the greatest disadvantage in using OPINT?

. Would you use OPINT in the future if it were made available to you? Please comment.

BIBLIOGRAPHY

ACCAT Operational Evaluation Task, (No Author), 1978.

Allen, J.J., Kelly, C.W. III, Phillips, L.H., and Stewart, R.R., Computer-Assisted Option Screening and Intelligence Assessment: Software User's Guide, Decisions and Designs Inc., October 1976.

Amey, Dorothy M., Feuerwerger, P. H., and Gulick, R. M., Documentation of Decision-Aiding Software: OPINT Functional Description, Decision and Designs, Inc., April 1979.

Amey, Dorothy M., Feuerwerger, P. H., and Gulick, R. M., Documentation of Decision-Aiding Software: OPINT Users Manual, Decisions and Designs Inc., April 1979.

Amey, Dorothy M., Feuerwerger, P. H., and Gulick, R. M., Documentation of Decision-Aiding Software: OPINT System Specification, Decisions and Designs Inc., April 1979.

Anderson, Virgil L. and McLean, R. A., Design of Experiments - A Realistic Approach, Marcel Dekker, Inc., 1974.

Andriole, Stephen J., "Another Side to C3", Defense Management Journal, May-June 1979.

Andriole, Stephen J., Another Side to C3: Computer Based Information, Decision, and Forecasting Systems, Cybernetics Technology Office, DARPA, January 1980.

Barclay, Scott, Brown, R. V., Kellog, C. W., Peterson, C. R., Phillips, Lawrence D., and Selvidge, J., Handbook for Decision Analysis, Technical Report TR 77-6-30, Decisions and Designs, Inc., September 1977.

Barr, D.R., Poock, G.K., and Richards, F.R., Experimentation Manual, Naval Postgraduate School, November 1978.

Brinkers, Henry S., Decision Making, Ohio State University Press, 1972.

Cain, David and Poh, S., An Experimental Technique for Evaluating Data Base Query Systems, The MITRE Corporation, March 1978.

Daly, Dr. Judith A., Early Warning and Monitoring System: Sample Output, Decision and Designs, Inc., January 1978.

Daniels, Thomas Lee, Design of an Experiment for the Evaluation of Threat Evaluation and Countermeasures Agent (TECA)- A Conceptual C2 Decision Aid, Thesis- Naval Postgraduate School, December 1977.

Decisions and Designs Inc., Introduction to EVAL and EVAL Structure, December 1977.

Department of the Army, Field Manual 101-5, Staff Organization and Operations, January 1980.

Keen, Peter G.W. and Scott Morton, M. S., Decision Support Systems: an Organizational Perspective, Addison-Wesley Publishing Co., 1978.

Lapin, Lawrence, Quantitative Methods for Buisness Decisions, Harcourt Brace Jovanovich, Inc., 1976.

Leal, Antonio, Levin, S., Johnston, S., Agmon, M., and Weltman, G., An Interactive Computer Aiding System for Group Decision Making, Perceptronics Inc., February 1978.

Madni, Ashad, Steeb, R., Rubio, D., and Farnum, R., Adaptive Information Selection for Support of C3 Functions in Small Tactical Units: Initial System Development and Software Documentation, Perceptronics, Inc., January 1979.

Mahoney, Robert B. Jr., Exectutive Aid for Crisis Management: Sample Output, CACI, Inc., November 1977.

Moose, Paul, Notes From C3 Class Titled C3 Policies and Problems, Naval Postgraduate School, January 1980.

Peterson, C.R. and Beach, L.R., "Man as an Intuitive Statistician", Psychological Bulletin 68:1, 1967.

Potter, Mary C., Kroll, J. F., and Harris, C., Comprehension and Memory in Rapid Sequential Reading, Department of Psychology, Massachusetts Institute of Technology, April 1979.

Rumsfeld, Donald, "A Command, Control, and Communications Overview", Signal, May/June 1976.

Sinaiko, H. Wallace, Operational Decision Aids: A Program of Applied Research for Naval Command and Control Systems, (ONR), July 1977.

Turban, Efraim, and Meredith, J. R., Fundamentals of Management Science, Buisness Publications, Inc., 1977.

Von Neuman, J. and Morgenstern, O., Theory of Games and Economic Behavior, Princeton University Press, 1944.

Williams, LTC Larry R., Modern Approaches to Defense Decision Making, U.S. Army War College Study Project, Carlisle Barracks, Pa., 12 May 1978.

Yates, Frank, Selected Papers of Experimental Design, Charles Griffin & Company Limited, 1970.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Professor John M. Wozencraft, Code 74 Chairman, C3 Academic Group Naval Postgraduate School Monterey, California 93940	3
4.	LTCOL Ronald J. Roland, USAF, Code 52RL Naval Postgraduate School Monterey, California 93940	5
5.	MAJ Lawrence C. Shackleton, USA 4593 Dryfuss Street Stuart, Florida 33494	5
6.	Professor Gary K. Poock, Code 55PK Naval Postgraduate School Monterey, California 93940	1
7.	CAPT Mike Hayes, USN DARPA/CTO 1400 Wilson Boulevard Alexandria, Virginia 22209	1
8.	Dr. M. Tolcott, Code 455 Office of Naval Research 800 N. Quincy Street Arlington, Virginia 20360	1
9.	Mr. Bruno Witte, Code 832 Naval Ocean Systems Center San Diego, California 92152	1
10.	Professor Gerald E. Thompson College of Buisness Administration University of Nebraska Lincoln, Nebraska 68588	1

11. Dr. M. Dencoff, Code 437 1
Office of Naval Research
800 N. Quincy Street
Arlington, Virginia 22217

12. Mr. C. C. Stout, Code 330 1
Naval Electronics System Command
2511 Jefferson Davis Highway
Arlington, Virginia 20360

13. Mr. John Summers 1
The MITRE Corporation
MITRE C3 Division
Washington C3 Operations
1820 Dolly Madison Boulevard
McLean, Virginia 22102

14. Mr. Jim Allen 1
Response Resource, Inc.
1310 Vincent Place
McLean, Virginia 22101